THE WORLD WAR II ORDNANCE DEPARTMENT'S GOVERNMENT-OWNED CONTRACTOR-OPERATED (GOCO) INDUSTRIAL FACILITIES: HOLSTON ORDNANCE WORKS HISTORIC INVESTIGATION

by
Mark Swanson
of
New South Associates

U.S. ARMY MATERIEL COMMAND HISTORIC CONTEXT SERIES
REPORT OF INVESTIGATIONS
NUMBER 9A

GEO-MARINE, INC.

US Army Corps
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Fort Worth District

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This report documents the construction and operation of Holston Ordnance Works, now known as the Holston Army Ammunition Plant, Kingsport, Tennessee. The research was initiated by Geo-Marine, Inc., in the spring and summer of 1995, and was continued by New South Associates in September and October of the same year.

Holston Ordnance Works was a critically important installation in the Ordnance Department's government-owned contractor-operated industrial program during World War II. It contributed to the war effort by producing most of the explosive RDX and Composition B (a mixture of RDX and TNT) used by the Western Allies. These explosives went directly into the war effort and were vitally important to Allied victory in the Battle of the Atlantic. Later, they were used in the aerial war over both Germany and Japan.

Due to the experimental and highly technical nature of the facility, Holston Ordnance Works was closely associated with its contractor, perhaps more so than most other Ordnance facilities. The operating contractor in this case was the Tennessee Eastman Corporation. Now known as the Eastman Chemical Company, TEC was then a subsidiary of the Eastman Kodak Company, based in Rochester, New York. Located in Kingsport long before the war, TEC was familiar with the manufacture of acetic acid and acetic anhydride, both essential to the making of RDX. This connection led to Kingsport as the site for Holston, with Tennessee Eastman selected to run it.

Due to the unique nature of this facility, Holston was divided into two parts. Area A, close to the original TEC manufacturing plant, produced and refined the acetic acid and acetic anhydride needed for the production of RDX. These were then shipped over to Area B, a few miles away, where the RDX was manufactured and combined with TNT to form Composition B, the final product of the Holston Ordnance Works. Area B also contained a nitric acid area (503 Area), an extensive series of magazines, as well as service and administrative areas.

In addition to the construction and operation of Holston Ordnance Works, this report addresses the effects of those activities on the city and region of Kingsport, home of Tennessee Eastman and a number of other industrial firms. Kingsport doubled in size as a result of the construction of Holston, and local housing was hard-pressed to meet the demand. Equally severe were the occupational demands placed on Holston employees, many of whom had never before worked in a factory, much less a top-secret explosives plant.

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HOLSTON ORDNANCE WORKS HISTORIC INVESTIGATION

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under
U.S. ARMY CORPS OF ENGINEERS
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MANAGEMENT SUMMARY

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In addition to the construction and operation of Holston Ordnance Works, this report addresses the effects of those activities on the city and region of Kingsport, home of Tennessee Eastman and a number of other industrial firms. Kingsport doubled in size as a result of the construction of Holston, and local housing was hard-pressed to meet the demand. Equally severe were the occupational demands placed on Holston employees, many of whom had never before worked in a factory, much less a top-secret explosives plant.

TABLE OF CONTENTS

Table of Contents
(cont'd)

LIST OF FIGURES

List of Figures
(cont'd)

ACKNOWLEDGMENTS

Many people contributed time and effort to bring this project to completion. Steve Gaither, of Geo-Marine, Inc. (GMI), canvased the records of the National Archives, Suitland Branch, for pertinent historical data on Holston Ordnance Works. This information proved essential in establishing a time line for the facility, and also provided valuable information on production figures and personnel. Duane E. Peter, Vice-President of GMI and Principal Investigator, provided essential guidance during the development of the project.

Equally valuable was the help provided by a great many individuals at Holston Army Ammunition Plant, currently operated by Holston Defense Corporation. Among those that must be named are: George Fletcher, Ernie Botts, Joe Davy, Robert Duram, John Detweiler, Jim Necessary, Linda McKamey, Bill Miller, Mike Mills, John Thomasson, David Stauffer, Jr., Don Henley, William Hill, and Carson Wilson.

Five former World War II employees of Holston Ordnance Works were formally interviewed in the course of this project. They were Raleigh Dingus, David Stauffer, Sr., Henry Collins, Raymond Herring, and Melvin Johnson. These people were a direct link to a time of tremendous effort and sacrifice, when Holston and the people who worked there made a substantial, and largely unsung, contribution to victory in World War II. It was an honor to interview these individuals.

This report could not have been produced without the assistance of several people at New South Associates. Joe Joseph and Mary Beth Reed contributed their time in editing this document, while Julie Cantley worked on the figures. Thanks go to all of these individuals, and others unnamed, that helped make this project both a pleasure and a success.

Thanks also go to Joseph Murphey of the U.S. Army Corps of Engineers, Fort Worth District, who was most supportive of our efforts. He provided constructive criticism and management direction throughout this project. In the Plano office of Geo-Marine, Inc., the final editing and overall production of the report were the responsibilities of Ms. Sharlene Allday, and Ms. Denise Pemberton generated the computerized format for the layout and design of the book.

CHAPTER 1
INTRODUCTION

This report is the result of historical research into the origins and development of Holston Ordnance Works, now known as the Holston Army Ammunition Plant (Holston AAP), in Kingsport, Tennessee. In September 1993, the U.S. Army Corps of Engineers, Fort Worth District, contracted with Geo-Marine, Inc. (GMI), to conduct research and documentation at a number of ammunition plants under the jurisdiction of the Army Materiel Command (AMC). This work was to mitigate the effects of "a program to cease maintenance . . . and dispose of certain . . . properties" owned by the government (Scope of Work [SOW] 1993:1). The investigation was extended to include Holston, and research was initiated in 1995 with Duane E. Peter, Vice-President of GMI's cultural resources management division, serving as Principal Investigator. Steve Gaither conducted the initial research at the National Archives; Mark Swanson with New South Associates, a GMI subcontractor, completed the research at Kingsport and Holston AAP. This work was performed under Contract No. DACA63-93-D-0014, Delivery Order No. 89, Detailed Investigation of World War II GOCO Facility - Holston AAP (Peter 1995).

This historical context is divided into two sections. The first deals with the facility itself: its origins, time line, and technology. It includes a discussion of local history before World War II; the development of Tennessee Eastman Corporation; the RDX story; and other aspects of the military and political situation between the wars salient to Holston Ordnance Works.

The second section discusses daily life at Holston, the personnel who ran the facility, and the impact of Holston on Kingsport and the surrounding area. Kingsport more than doubled in size during the war, and this put a great strain on the community. Unlike some other ordnance facilities, there was no appreciable ethnic influx at Holston since relatively few African-Americans or other minority groups lived in the labor pool area of northeast Tennessee and southwest Virginia. There was, however, a sizable percentage of women who worked at Holston, and this was very much at odds with pre-war hiring practices in the area. This section concludes with the impact of the end of the war on Holston and a discussion of its rebirth in the decades that followed.

CHAPTER 2
OBJECTIVES AND METHODS

STATEMENT OF OBJECTIVE

The aim of this project at Holston Ordnance Works (now Holston Army Ammunition Plant [AAP]), Kingsport, Tennessee, was to provide an "understanding of the World War II military-industrial complex through detailed examination of [six] sample installations" (Scope of Work [SOW] 1993:4). This project was designed to augment the national historic context of such facilities by including issues of state and local significance. The national context, also referred to as Task A, was examined in Kimberly Kane's (1995) *Historic Context for the World War II Ordnance Department's Government-Owned Contractor-Operated (GOCO) Industrial Facilities, 1939-1945*. Research on Holston Ordnance Works was part of Task B, the study of the six sample installations and their immediate environs. The focus of Task B work at Holston was to examine the unique development of the facility, and to concentrate on various World War II social issues of state and local importance. Among these issues were land acquisition, development of the local labor force, and potential changes in that force due to the introduction of previously marginal groups, such as women and ethnic minorities (SOW 1993:4).

This work was part of a larger project, which was to "research and document World War II and earlier buildings and structures at a number of ammunition plants under the jurisdiction of the Army Materiel Command (AMC) as a Legacy Resource Program demonstration project for assistance to small installations," and to "fulfil mitigation efforts of a 1993 Programmatic Agreement among the AMC, the Advisory Council on Historic Preservation, and multiple State Historic Preservation Officers concerning a program to cease maintenance, excess, and dispose of certain properties" (SOW 1993:1).

METHODS

Holston Ordnance Works was constructed between 1942 and 1944. Pilot plant operations began turning out Composition B in the first half of 1942, but regular production lines did not begin operation until May of 1943, with production accelerating throughout 1944 and early 1945. It has been estimated that Holston produced 90 percent of the RDX and Composition B manufactured by the United States during World War II. This was a staggering contribution to the American war effort. In order to understand Holston's contribution to World War II, a brief treatment of the national military and political setting has been included in this report. A more detailed account of the national setting is presented in the first volume of this series, *Historic Context for the World War II Ordnance Department's Government-Owned Contractor-Operated Industrial Facilities, 1939-1945* (Kane 1995).

Much of the material pertinent to Holston was found at the Suitland Reference Branch of the National Archives in Record Group 156. This included the volumes of the official history of the Holston facility, compiled as production progressed, as well as numerous reports on special processes and experiments. Complementary information was also found in standard works on military and engineering history.

Valuable information was also found at Holston AAP. Several people presently working at Holston had family members employed by the plant during World War II. There was also a great amount of original data on file at the plant. The Engineering Vault in Building 26 contains most of the original engineering drawings and many original photographs. Other information was kept in the Old Purchasing and Payroll Records Vault, Room 223, in Building 26.

To supplement the textual information gathered at Holston, five oral interviews were conducted with people who had direct contact with Holston during World War II. Many of the interviewees were local residents when the war began, and some had prior experience at the Tennessee Eastman Corporation (TEC).

CHAPTER 3
HISTORIC CONTEXT FOR HOLSTON ARMY AMMUNITION PLANT, A WORLD WAR II ORDNANCE DEPARTMENT GOCO INDUSTRIAL FACILITY, 1942 - 1995

INTRODUCTION

Importance of Holston Ordnance Works

Holston Ordnance Works, now identified as Holston Army Ammunition Plant (Holston AAP or HSAAP), is located in the vicinity of Kingsport, Tennessee, adjacent to the junction of the North and South forks of the Holston River (Figure 1). Construction began on Holston in June of 1942, and was completed in early 1944 with the full operation of 10 production lines. Production commenced in May of 1943, while construction was still in progress.

For safety reasons, Holston was divided into two noncontiguous parts, Area A and Area B, sometimes referred to as Plant A and Plant B. Area A was located in Sullivan County, immediately southwest of Kingsport, along the South Fork of the Holston River. During World War II, this area was set aside for the manufacture and refinement of acetic acid and acetic anhydride, chemicals needed in the production of RDX. Area B, located four miles to the west in Hawkins County, was the site of the 10 production lines and most of the support facilities needed to keep them running. The production lines were located in the 506 Area; the 503 Area was set aside for the storage and purification of nitric acid. In addition, there were magazines, service areas, and an administrative center. Both Areas A and B were protected by perimeter fences and connected by transmission lines and an interplant railroad system.

Holston Ordnance Works was constructed to produce RDX, the world's most powerful explosive until the atom bomb. Because RDX was too unstable to be used in its pure form, it had to be mixed with other materials or explosives. During World War II, Holston was also designed to mix RDX with TNT, usually to the ratio of 60:40. The resulting combination, known as Composition B, was vital to the Allied war effort, first in the anti-submarine campaign of 1942 and 1943, and then later in aerial bombs.

As the world's largest producer of Composition B, Holston played a key role in the nation's munitions production during World War II. Like other munitions plants during the war, Holston was a government-owned contractor-operated (GOCO) facility. In other words, the government bought the land and paid for the construction of the facility, but hired a private firm to run and manage the operation. This was done through a cost-plus-fixed-fee contract (Holston Ordnance Works [HOW] 1945b:II:10). Holston

was one of the last GOCO facilities to go into production during World War II, and this was largely because of the difficult and experimental nature of RDX production during the early war years.

The company that built Holston was Fraser-Brace Engineering, based in New York. The company that ran Holston was Tennessee Eastman Corporation (TEC), which operated under contract to the National Defense Research Committee and the Ordnance Department (Englander 1946:15). The TEC, later known as the Tennessee Eastman Company, and finally the Eastman Chemical Company, was then a subsidiary of Eastman Kodak in Rochester, New York. Months before the Holston contract was let, Tennessee Eastman was involved in RDX research. This research led to the construction and operation of two TEC pilot plants known as Wexler Bend and Horse Creek. The first made RDX and the second made Composition B. Even though these pilot plants pre-dated Holston, the GOCO plant cannot be understood without reference to these early TEC facilities.

While Holston's contribution to the World War II effort was significant, the facility also played an important role during the conflicts in Korea and Vietnam. During this time, production of RDX and Composition B were complemented by new and improved variations, like HMX and the various Composition C mixtures. The Holston Defense Corporation, a subsidiary of TEC, was established in 1949 to run the facility. Holston Ordnance Works was renamed Holston Army Ammunition Plant in 1963—the name it bears today (Holston Defense Corporation c. 1990:4). Since the end of the Vietnam War, Holston production has been on a steady slide. Production now occurs in only a few buildings and is the equivalent to the output of a single production line. For this reason, a reduction in the number of facilities at Holston is being considered, and even closure of the entire facility is possible.

Natural Setting

Together with the Powell, Clinch, and Nolichucky rivers, the Holston River forms the upper watershed of the Tennessee River. This watershed drains from northeast to southwest and covers the area between the Cumberland Ridge along the Kentucky-Virginia border and the high Appalachian Mountains in North Carolina. The Holston drainage area corresponds to what is now southwest Virginia and northeast Tennessee.

Situated in the northeast corner of Tennessee, just three miles from the Virginia line, Kingsport is located along the north bank of the South Fork of the Holston River, at an elevation of 1,300 feet above sea level. Bays Mountain, a local landmark across the river and two miles to the southwest, reaches a height of approximately 2,000 feet. Clinch Mountain, another visible landmark several miles north and west of Kingsport, is close to the same height. Kingsport itself is located adjacent to a four-mile island in the middle of the river, usually referred to as "Long Island."

Long Island and modern Kingsport are situated approximately two miles above the confluence of the North and South forks of the Holston. The North Fork, which drains the southern slopes of Clinch Mountain, is considerably smaller than the South Fork. Immediately above the confluence, the North Fork is marked by steep heights on both sides of the river. For all practical purposes, the North Fork has never been navigable. The South Fork, a much larger stream, was at least partially navigable before the Tennessee Valley Authority (TVA) built hydroelectric dams throughout the upper Tennessee watershed.

Early History of Kingsport and Tennessee Eastman

The local significance of the Holston Ordnance Works is rooted in the early history of Tennessee and the subsequent development of Kingsport as a site for explosives production. From the first historic settlement in Tennessee, the Holston River would play an important role in attracting settlers and certain types of industry. Figure 2 provides the location of some sites pertinent to the pre-Holston history of Kingsport.

Figure 1. Kingsport, Holston Army Ammunition Plant, and vicinity (from TVA Map 1967).

1


Cedar Grove Sch
Beartown
West View Park
KINGSPORT CEM
KINGSPORT
108,000
Nelsontown
Howard Hill
SOUTH
FORK
HOLSTON
RIVER
CLOUDS BEND
KILNS
Borden Village
AREA A
Fairfield Ch
Long Island
Beechwood Village
90,000

2

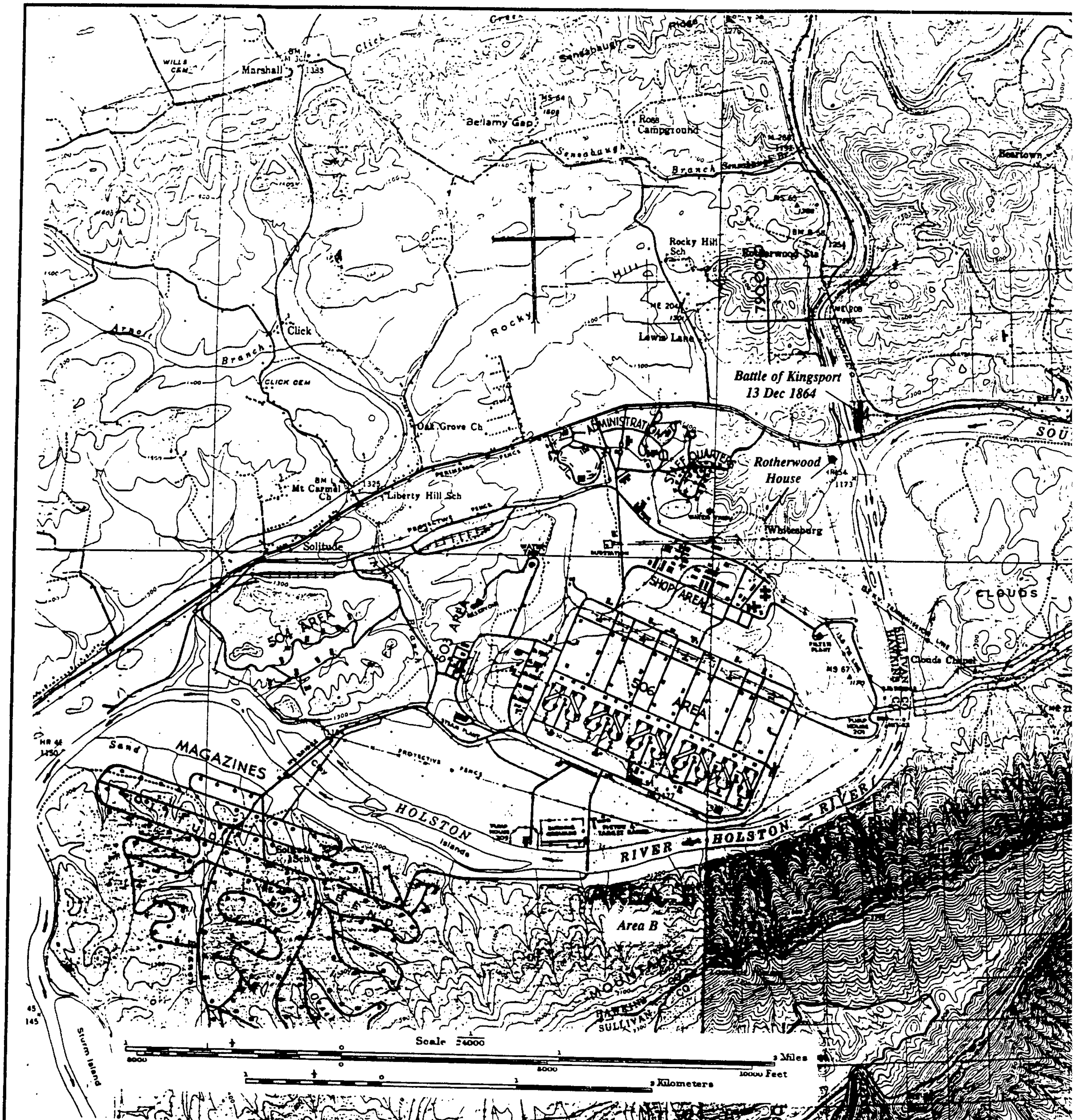
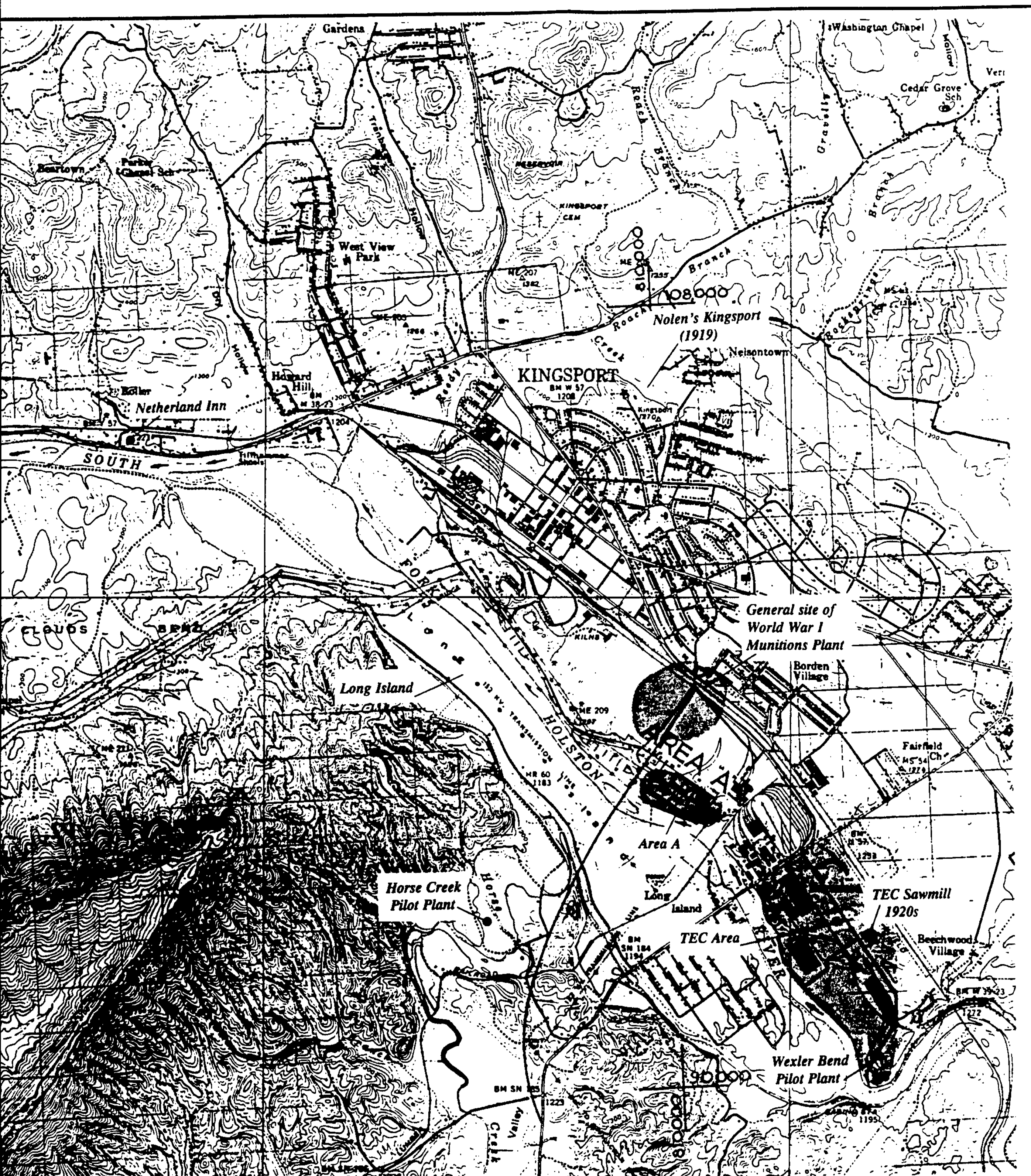


Figure 2. Location of some early historical features in vicinity of Holston Ordnance Works (from City of Kingsport 1994).



Gardens
Washington Chapel
Cedar Grove Sch
Beartown
West View Park
Nolen's Kingsport (1919)
Nelsontown
KINGSPORT
Howard Hill
Netherland Inn
SOUTH
FORK
HOLSTON
RIVER
General site of World War I Munitions Plant
Borden Village
Long Island
Fairfield Ch
AREA A
Area A
Long Island
Horse Creek Pilot Plant
TEC Sawmill 1920s
Beechwood Village
TEC Area
Wexler Bend Pilot Plant

2

The junction of the North and South forks of the Holston was first recorded in 1750 by Thomas Walker, who was exploring territory outside of the British colonies that were established along the Atlantic seaboard. A few years later, during the French and Indian War, British-American colonists set up at least two forts in what is now east Tennessee—Fort Loudon, on the Tennessee River, 30 miles below what is now Knoxville, and Fort Robinson, along the Holston River at Long Island (Long 1928:10-24). Neither fort endured, and when Daniel Boone passed through the area in 1769 en route to Kentucky, he passed through an area that was still Cherokee land (Long 1928:7).

In the mid-1700s, the Cherokee were centered around the mountains of what is now Tennessee, North Carolina, and Georgia. By the 1770s, British-American colonists from Virginia and North Carolina began to move into the extreme northeast corner of what is now Tennessee. The American Revolution only encouraged the influx of settlers. Most of the newcomers were Scotch-Irish, though some were of German, English, and French heritage. These settlers migrated down the valleys of the Appalachians from Pennsylvania, beginning in the early 1700s (Fischer 1989:633-634; Long 1928:72; Rotary Club 1946:9). By 1776, local settlers had established Fort Patrick Henry on Long Island; the following year, the island, and much of the area around it, was ceded to the new settlers by treaty with the Cherokee (Long 1928:24; Rotary Club 1946:7). Sullivan County was created just a few years later (Rotary Club 1946:6). This began a 50-year period in which the Cherokee were dispossessed of all of the upper Tennessee River valley.

During much of this time, the upper Tennessee watershed was subject to uncertain political boundaries. At first, the whole area was thought to belong to Virginia. Later, it was split between Virginia and North Carolina, but most colonists were not satisfied with the arrangement. In the mid-1780s, Jonesboro, the oldest town in what is now Tennessee, became the first capital of the State of Franklin, a premature secession from North Carolina (Rotary Club 1946:124). Tennessee finally became a state in its own right in 1795.

Even though towns sprang up along the Tennessee River and its upper tributaries, the Kingsport area remained a region of isolated settlements connected only by the Holston River. Kingsport is believed to have received its name from Col. James King, who established a mill at the mouth of Reedy Creek on the Holston River in 1774. Later, he set up a boatyard to facilitate shipping downstream to Knoxville, and it was from this "King's Port" that the Kingsport area got its name (Long 1928:37; Rotary Club 1946:5). In the early 1800s, the Kingsport/Long Island area was dominated by Col. George W. Netherland, a local slave-owner who built the Netherland Hotel in 1811. The hotel was a popular local meeting place, and became a favorite stop-over for Presidents Andrew Jackson and James Polk on their trips between Nashville and Washington, D.C. (Long 1928:24, 49).

Rotherwood, the home of Holston's army commanders during World War II, originated when Dr. Frederick A. Ross established an estate in 1818 on the west bank of the North Fork, just above the confluence. The first residence, now gone, was constructed overlooking the river and was named "Rotherwood." A great fan of Sir Walter Scott's novels, Ross named his house after the castle of Cedric the Saxon in *Ivanhoe*. It soon became the most impressive structure in the Kingsport area (Long 1928:37, 52-59; Rotary Club 1946:15-19). In 1823, Dr. Ross married Theodocia Vance of Jonesboro, and their daughter Rowena was named after the Saxon heroine of the same novel. The present Rotherwood house was built for Rowena in 1850, a few hundred yards below the original Ross mansion, which was destroyed during the Civil War (Long 1928:56, 60-61).

Ross lost his entire estate in 1852 as a result of a failed cotton factory. The property was then purchased by Joshua Phipps and remained in the Phipps family for the remainder of the century. In the early 1900s, the property was bought by Kingsport Farms. By 1928, it was in the possession of John B. Dennis, who ran a prosperous dairy farm and worked to make Rotherwood a local show-place (Long 1928:59, 60-61). The Army inherited Rotherwood when the dairy farm was purchased as part of Holston's Area B (Figure 3).

Figure 3. Rotherwood House, circa 1943 (courtesy of Holston AAP Photo Set No. 41-B [on file Engineering Vault, Building 26]).

Despite the presence of Col. Netherland and Dr. Ross, the plantation system never really flourished in east Tennessee. Most of the local Scotch-Irish inhabitants were adverse to slavery and rarely had the money to develop large land holdings. Equally important, the soil and cool climate were not conducive to cotton. As a result, east Tennessee never really became tied to the slave-owning aristocracy of the Deep South.

East Tennessee became part of a regional rail system in the 1850s. Known as the "East Tennessee, Virginia, and Georgia," the line connected the major cities of east Tennessee, but skirted around the Kingsport area. A boon for Knoxville, Bristol, and other towns along the line, the railroad devastated Kingsport's river commerce which evaporated in the years that followed (Rotary Club 1946:12-13). During the Civil War, commerce suffered even more.

Unlike some southern states, Tennessee was bitterly divided over the issue of secession. This was particularly true in east Tennessee, where slavery was not common and the ensuing conflict was perceived as a "rich man's war and a poor man's fight." Pro-Union sentiment ran so high that Confederate troops had to be sent to Knoxville to preserve order in June of 1861. It is ironic then that east Tennessee, the most pro-Union portion of the state, was the last to be recaptured by Federal forces. Knoxville was not captured until early September of 1863, and the extreme northeast portion of the state remained in Confederate hands for more than a year after that.

This situation was finally altered by Union General George Stoneman's campaign into southwest Virginia. With about 5,000 cavalry, Stoneman set out from Knoxville on 10 December 1864, en route to Saltville, Virginia, where he planned to destroy extensive Confederate saltworks and railroad supplies. Traveling up the South Fork of the Holston on the west bank, Stoneman encountered a small Confederate force near the mouth of the North Fork. After driving the Confederates across the North Fork, Stoneman succeeded in crossing the river on the morning of 13 December. Most of the 350 Confederates were captured in a flanking movement that has come to be known as the battle of Rotherwood or Kingsport, 13 December 1864. Stoneman continued on to Saltville and his forces plundered and looted throughout the area (Long 1928:73-75; Rotary Club 1946:20; Stoneman 1864).

The three decades that followed the Civil War were the bleakest in Kingsport history (Long 1928:75-77). The local economy was ruined, and the demise of river traffic made it difficult to establish connections with outside markets. This situation was not altered until the coming of the Carolina, Clinchfield, and Ohio Railroad in the early 1900s.

Now known as the Clinchfield Railroad, the Carolina, Clinchfield, and Ohio line traversed the southern Appalachians from Elkhorn City, Kentucky, to Spartanburg, South Carolina, making use of every imaginable valley and gorge in between. The rail line entered the Kingsport area in 1909, with the entire line completed in 1915 (Rotary Club 1946:21; Wolfe 1987:4, 17). In the years that followed, the Clinchfield was joined by another line, the Southern Railroad, which passed immediately west of town. The Clinchfield and Southern railroads invigorated the area economy, including the small community of Kingsport. Kingsport was finally incorporated in 1917 (Rotary Club 1946:1), just about the time the United States was directly involved in World War I.

The United States had been selling arms and supplies to the Allies for a number of years before declaring war against Germany in April of 1917. Despite this involvement, the United States found itself largely unprepared for a modern war. An army had to be trained and equipped, and the nation's ordnance situation was nothing short of chaotic. Nitrates were essential to the production of TNT, then the most powerful explosive that could safely be used, and it caused something of a national panic when nitrates had to be imported from Chile. This led to war-time plans for a massive Tennessee River dam at Muscle Shoals, Alabama, which would provide electric power for an equally massive set of nitrate plants (Schlesinger 1983:18-23, 99-101).

None of the Muscle Shoals works was completed by the time the war ended on 11 November 1918, but other war-time munitions plants were already in full swing throughout Tennessee. The Old Hickory Munitions Works, operated on the Cumberland River by DuPont, the nation's largest explosives manufacturer, is believed to have been the largest munitions factory in the United States during World War I. It had a work force reported to total 75,000 by Armistice Day (Schlesinger 1983:18-23).

Kingsport was not immune to the new spate of war industries. Three "war babies," all temporary, set up shop in Kingsport: the Federal Dyestuff and Chemical Corporation, the American Wood Reduction Company, and Edgewood Arsenal. The first two produced chemicals for the war effort, while the Edgewood Arsenal loaded shells and made tear gas. All of these plants are believed to have been located in the vicinity of Lincoln Street and South Wilcox Drive, less than half a mile from the South Fork of the Holston (Joe Davy, personal communication 1995). The Edgewood Arsenal was just preparing to go on line when the war ended (Wolfe 1987:59). In the months that followed, much of this war-time stock of chemicals and munitions was simply buried in the floodplain along the river, only to be found again when Area A was under construction some 24 years later (Doerr 1945:2-9).

World War I had a great impact on the region and on Kingsport, if only to lay the groundwork for what was to follow. The TVA eventually grew out of war-time plans for a dam at Muscle Shoals (Schlesinger 1983:99-101). The war brought the first chemical industries to Kingsport, and others soon followed. Within two years of the war, Tennessee Eastman moved into Kingsport and eventually became the largest chemical operation in the entire region.

Tennessee Eastman might never have come, however, if Kingsport had not touted itself as a planned city dedicated to industrial development. Such was the dream and work of one man, J. Fred Johnson, later known as the "Father of Kingsport" (Wolfe 1987:149). Johnson, as president of the Kingsport Improvement Company, was instrumental in developing the town's infrastructure in the late 1910s; later, he became the city's powerbroker (Long 1928:88; Wolfe 1987:57). He established the very look of Kingsport by attracting the services of Dr. John Nolen, a city planner and engineer from Cambridge, Massachusetts (Rotary Club 1946:31-33).

Nolen's plan for Kingsport was laid out in 1919 in a "General Map of Kingsport, Tennessee" (Figure 4). The plan called for a city of some 50,000 inhabitants, with people living and working in three separate areas of town. The highest elevations furthest from the river were to be residential; the level tracts above the floodplain would be reserved for business; the flood plain adjacent to the river would be exclusively for the use of industry (Rotary Club 1946:31-33). This plan was established during World War I, and the pattern held in the years that followed. It also established a social pattern that was to mark Kingsport as a unique community. The work force attracted to the city was overwhelmingly local and Appalachian, whereas the managerial force was usually imported from areas outside the South (Wolfe 1987:9).

In the 1910s and 1920s, a number of industries had moved into the area. One of the first was the Kingsport Brick Corporation, which was able to produce 135,000 bricks a day by 1928 (Long 1928:165-166). Other industries included a hosiery mill, a book manufacturing plant, a cotton spinning mill, and a methanol or wood alcohol distillation plant set up by Tennessee Eastman (Rotary Club 1946:28). Tennessee Eastman would soon become the most successful of these new industries.

The TEC was established locally in 1920 as a subsidiary of the Eastman Kodak Company of Rochester, New York. Founded by George Eastman, the Kodak Company had already established itself as the country's greatest producer of photographic materials, including film. Tennessee Eastman distilled wood alcohol or methanol that was essential for the production of Eastman film in Rochester. In order to produce methanol, TEC acquired some 40,000 acres of timberland throughout the area, ran a large saw mill to process the wood, and turned out lumber as a by-product (Rotary Club 1946:130, 137).

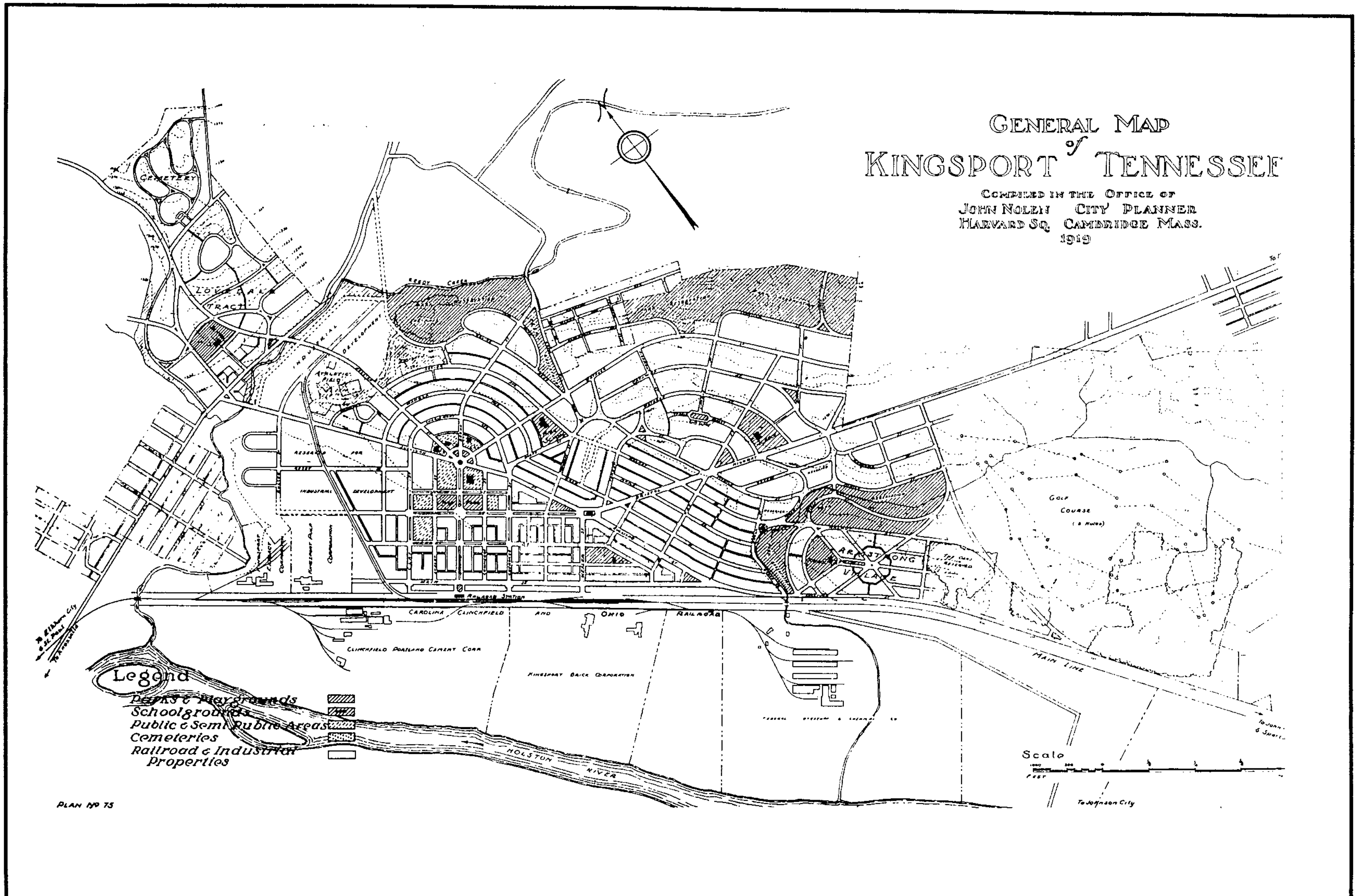


Figure 4. John Nolen's Plan for Kingsport, Tennessee, 1919 (Wolfe 1987:Frontispiece).

By 1928, when Howard Long published his book on Kingsport, the TEC was already a large company. An extensive network of railroad spurs was used to haul timber back to the plant, located in the area now bounded by Lincoln Street, the John B. Dennis Highway, and the North Fork of the Holston. There, a modern saw mill cut the timber into lumber, sending only the waste-wood to the methanol distillation works (Long 1928:226-227). TEC also produced charcoal, methyl acetone, acetate of lime (calcium acetate), and a popular wood preserving oil sold commercially as "No-D-K" (Long 1928:107, 225).

In addition to methanol and methyl acetone, which were essential to the production of photographic film, Long noted that TEC was also producing quantities of acetic acid and acetic anhydride, important ingredients in Kodak's new and highly popular nonflammable "safety" film, marketed under the name of "Cine-Kodak" (Long 1928:223, 234). To produce all of these materials, TEC employed 422 people and processed 325 tons of wood each day (Long 1928:223).

Even in 1928, Tennessee Eastman was noted for its conservation practices. TEC had its own reforestation program and was known for exploiting all of its cut timber, right down to the sawdust (Long 1928:112-116). More radical, perhaps, were the first experiments in wood distillation which used the "continuous retort process" (Long 1928:224). From this humble beginning came the venerable TEC tradition of the "continuous feed" process. This process was later used in the production lines at Holston when raw materials to make RDX were transferred from one building to the next in a semi-fluid, instead of dry, form.

The increased popularity of nonflammable Kodak film in the 1930s led to a dramatic increase in production of cellulose acetate, an essential raw material for the film. Cellulose acetate was made by treating cotton linters with two chemicals—acetic acid and acetic anhydride (Rotary Club 1946:137-139; Wolfe 1987:140). Thus, production of both chemicals increased at TEC.

Acetic anhydride, essential for the manufacture of safety film, was distilled from concentrated (or glacial) acetic acid. First, acetic acid was combined with a catalyst and then heated. This broke the mixture down into water vapor and ketene gas. Ketene was then combined with glacial acetic acid in a "scrubbing process" that produced crude acetic anhydride. This was then distilled to make pure acetic anhydride with a residue of spent acetic acid (Kane 1995:151).

To complement the production of acetic anhydride, TEC developed a continuous recovery system for acetic acid (Burton and McNeeley 1944:21; MacDonald and Mack Partnership [MacDonald and Mack] 1984:19). By this method, TEC chemists were able to take spent acetic acid, diluted with water, and re-concentrate it to full strength by "removing the water azeotropically, using propyl acetate as the entraining agent" (Burton and McNeeley 1944:21).

Once TEC could successfully produce acetate, the company branched into other compatible areas, foremost of which was plastics. A cellulose acetate molding composition, marketed as "Tenite," was the first foray by TEC into plastics. Tenite I appeared in 1933; Tenite II followed in 1940 (Wolfe 1987:140). Acetate yarn, or rayon, was also developed (HOW 1943a:XIII:23; Rotary Club 1946:139-140).

During the 1930s, Tennessee Eastman matured into a highly successful company and continued to expand throughout the period when other firms were hard hit by the economic depression. By 1940, TEC could boast of having nearly 100 buildings, situated on 375 acres, and a staff of at least 5,000 people (Rotary Club 1946:139-140; Wolfe 1987:140). The company had a reputation for thrift, fairness, and resource conservation. They were also known for establishing the continuous process in chemical production, rather than using the more common batch method (Joe Davy, personal communication 1995).

By 1940, Tennessee Eastman was the economic giant of Kingsport, and it contributed to the general prosperity of the region. In that year, the census reported that Kingsport had a municipal population of 14,404, with another 30,000 people within a two-mile radius of the city limits (Wolfe 1987:140). Kingsport

was complemented by two other cities (Johnson City, Tennessee, and Bristol, Virginia), each located about 25 miles away and with comparable populations. Together, the three were known as the Tri-Cities and were interconnected through airports, rail lines, and highways (Englander 1946:16). TVA dam construction, underway since the early 1930s, provided hydroelectric power from Cherokee Dam, 50 miles downstream, on the Holston River (Englander 1946:16).

Kingsport and Tennessee Eastman were well-established and prosperous on the eve of World War II. Tennessee Eastman managed the most up-to-date processes to exist for acetic anhydride production and acetic acid refinement. Both were vital to the production of Kodak safety film and certain plastics. Unknown to most TEC personnel, both chemicals were also essential to the manufacture of RDX, an unstable high-explosive that had just been harnessed by the British, using the batch method of production. Prior to the Japanese bombing of Pearl Harbor in December of 1941, and immediately thereafter, the U.S. government sought a more efficient way to produce RDX. This initiated the collaboration between Tennessee Eastman and the Ordnance Department, as well as other government agencies, and led to the establishment of Holston Ordnance Works. Discussion of Tennessee Eastman's experimentation with RDX and the development of the Ordnance Department and the GOCO system is presented in the following sections.

MILITARY AND POLITICAL SETTING

Early Explosives and the Development of the Ordnance Department

At the time of the Civil War, black powder was the only common explosive in use, and had remained virtually unchanged since the introduction of cannons and matchlocks toward the end of the Middle Ages. Composed of sulphur, charcoal, and saltpeter (potassium nitrate or sodium nitrate), black powder had been the mainstay of warfare since at least the sixteenth century (Cairns 1942:162-163).

The first real improvement in explosives was smokeless powder, discovered in 1845 but not successfully manufactured until 40 years later. Smokeless powder was made when cellulose, in the form of cotton or wood pulp, was mixed with nitric and sulfuric acids to make nitrocellulose. When mixed with alcohol and ether, nitrocellulose became a gelatinized mixture that was then dried and cut into small pieces or "grains" (Cairns 1942:163; Kane 1995:127).

Smokeless powder, like black powder, was a single-based explosive, made from what was basically one chemical reaction. More sophisticated chemistry soon followed, with double-based explosives like nitroglycerine (glyceryl trinitrate) and trinitrotoluene (TNT). Highly unstable, nitroglycerine was harnessed in the late 1800s, and when mixed with the proper minerals, formed dynamite (Cairns 1942:164).

In the early 1900s, the relatively stable trinitrotoluene became the explosive most favored by the military. Commonly known as TNT, trinitrotoluene was made by nitrating toluene, a substance derived from coal tar. The nitrating substance most commonly used was ammonium nitrate, which was soon in high demand throughout the explosives industry. Another chemical in great demand was picric acid, especially in the form of ammonium picrate (Cairns 1942:165; Van Gelder and Schlatter 1972:938-944). With the development of TNT, a division formed between the older single-based low explosives and the newer double-based high-explosives. Low explosives, like smokeless powder, were still used as propellants (powder for shells). Double-based high-explosives, like TNT, burned fast and exploded with shattering, almost uncontrollable, effect (Kane 1995:125, 127). Thus, they were ideal for use in artillery shells, but too powerful to use as propellants. Some were also too sensitive to use *with* propellants and had a tendency to explode upon firing. In fact, this problem was germane to all high-explosives. Chemically complicated and unstable, they had to remain intact while being fired or handled, survive the initial impact, and detonate only when the fuse went

off. The ability of TNT to remain "true to the fuse" made it the preferred explosive during World War I (Green et al. 1990:366).

In the United States, most TNT production was handled by E. I. DuPont de Nemours Company and its affiliates. DuPont had been forced to split into three separate companies in 1912 when it was sued under the Sherman Anti-Trust Law (Van Gelder and Schlatter 1972:126). The split, however, was more technical than real, and all three firms, the DuPont Company, the Atlas Powder Company, and the Hercules Powder Company, received most of the nation's high-explosives contracts during World War I (Kane 1995:41).

Aside from the production of TNT, the nation's ordnance situation during World War I was described afterwards as "nearly a perfect mess" (Gaither 1995:12; Hewes 1975:29). Because there had been no pre-war procurement system, there was little coordination between suppliers of necessary materials and the production facilities. At one point there were over 150 War Department committees competing against each other to purchase materials on the open market (Gaither 1995:12; Hewes 1975:28). Factories, which quickly proved to be unnecessary, were constructed. And finally, there was often a discrepancy in the supply of integrally related parts, i.e., "more guns than gun carriages, more gun carriages than recuperators, more machined shell bodies than booster assemblies" (Green et al. 1990:25) and the integral products, and there was often an imbalance in the ratio of materials. The war ended, however, before these problems were adequately addressed (Green et al. 1990:24-25).

The National Defense Act of 1920 was designed to prevent a recurrence of the World War I ordnance experience. In addition to reorganizing the War Department, the Act specified that all military procurement was to go through the Assistant Secretary of War to prevent unnecessary competition between the Army and Navy. As a result of the Act, the Assistant Secretary established the Planning Branch, Office of the Assistant Secretary of War, which led to the Army and Navy Munitions Board in 1922. This board oversaw the coordination of ordnance procurement during the period between the wars (Kane 1995:14).

The Army and Navy Munitions Board worked with the Office of the Chief of Ordnance and the Manufacturing Service of the Ordnance Department during this time to ensure ordnance production and delivery. Most of this work was done by the Ordnance Department, which was divided into three branches: the General Office, which handled administration; the Field Service, which maintained and distributed materiel; and the Manufacturing Service (after 1938, known as the Industrial Service) in charge of materiel design and manufacture (Gaither 1995:13; Green et al. 1990:32-33). It was the Industrial Service wing of the Ordnance Department that would oversee the GOCO facilities during World War II.

The Industrial Service conducted most of its procurement through two entities, the ordnance districts and the established arsenals. The ordnance districts, set up around the country during World War I, kept tabs on potential contractors that could be switched to munitions production in case of war. The six "old-line" arsenals, left over from World War I, were assigned to preserve information necessary to produce war materiel. Picatinny Arsenal, in New Jersey, was dedicated to artillery ammunition, propellants (low explosives), and high-explosives (Kane 1995:19-21).

With their detailed ordnance knowledge and blueprints, the arsenals were the seed-beds of the Ordnance Department, from which it expected to cultivate the vast munitions-production system in the event of war. It was assumed that the vast majority of the industrial facilities needed for the production effort would be built and operated by private industry, which had the necessary knowledge and experience in industrial organization and production to undertake such a task. It was also assumed that these facilities would be government-owned since the government would have substantial financial resources during war-time (Gaither 1995:14). These assumptions guided the rapid expansion of the GOCO program in the early days of World War II.

Few of these plans, derived by the Ordnance Department, were put into effect until the end of the 1930s. In the years following World War I, there was a resurgence of traditional American isolationism. In the disastrous aftermath of the Versailles Treaty, many Americans came to feel that the United States involvement in the war had been a mistake, foisted on the public by unscrupulous munitions manufacturers. It was not until the late 1930s, when Germany and Japan posed a clear threat to peace, that Congress loosened any purse strings for the Ordnance Department.

On 8 September 1939, in response to the German invasion of Poland and the declaration of war by Britain and France, President Roosevelt declared a "State of Limited National Emergency." Before the year was out, Congress had altered American neutrality laws so that the Western Allies could buy American war materiel. These transactions began almost immediately through the Anglo-French Purchasing Board (Kane 1995:29).

After six months of virtually no activity on either side, the war in Europe intensified in April, May, and June of 1940. German forces overran Denmark and Norway before turning their attention to the Low Countries. By the end of May, the Germans had cut through British and French defenses to establish themselves on the Channel. This left the British Expeditionary Forces pinned at Dunkirk. In June, France collapsed, leaving Britain alone to face Nazi Germany. The fall of France was a profound shock to the American public and it quieted most of the isolationists in Congress. That summer, the United States began to prepare seriously for war.

In June of 1940, the War Department Site Committee decided that all new munitions plants should be constructed between the Appalachian and the Rocky mountains, and at least 200 miles from the Canadian and Mexican borders. Even though this recommendation was not always followed, it did mean that the vast majority of the new GOCO facilities were established in the lower Midwest and upper South (Kane 1995:23-24).

The first wave of GOCO facilities construction began in the summer and fall of 1940. British demand for materiel and the expansion of U.S. armed forces spurred the need for GOCO facilities. The first of the new facilities were the Indiana Ordnance Plant, in Charlestown, Indiana, and the Radford Ordnance Works, in Radford, Virginia. Construction of these facilities, through DuPont, began in late summer and early fall (Kane 1995:43-44; Thomson and Mayo 1991:111-112).

Both Radford and Indiana were smokeless powder plants. A TNT plant (Kankakee), a shell and bomb-loading plant (Ravenna), and another loading plant (Elwood) soon followed. In late summer of 1940, an explosion at the privately owned Hercules smokeless powder plant in Kenvil, New Jersey, caused the government to alter the layouts of both Radford and Indiana, then in the middle of construction, to create more space between production lines (Thomson and Mayo 1991:110-111, 131).

In addition to Ordnance-administered GOCO facilities, the British also worked directly with private companies for the production of war materiel. This occurred as early as August of 1940, when the British contracted with DuPont to build a large smokeless powder plant at Millington, Tennessee. Most privately operated facilities were folded into the GOCO network in 1941. At that time, the Millington Powder Plant was renamed the Chickasaw Ordnance Works (Thomson and Mayo 1991:110).

By December 1940, the British were nearing the end of their ability to pay cash for munitions. This led to the Lend-Lease Act of March 1941, which was another step toward direct involvement in the war (Kane 1995:44, 48). By the terms of this Act, the U.S. government took charge of all overseas orders for munitions, and then lent or leased the materiel directly to select "non-aggressor" nations, namely Britain (Kane 1995:44).

The Lend-Lease Act and the "State of Unlimited National Emergency" (27 May 1941) declared by Roosevelt after increased British shipping losses in the Atlantic, led to the 1941 GOCO expansion program that included the construction of 25 new facilities and the expansion of older ones. Thirteen of these new plants were bomb, shell, and fuse-loading operations—five made ammonia, two made oleum and ammonium picrate, two made smokeless powder, and three were designed to make TNT (Thomson and Mayo 1991:111).

As GOCO production got underway, the Ordnance Department was plagued by a number of imbalances in supplies and materials. Foremost was a glut of shells and casings, and not enough powder, explosives, and fuses to arm them (Thomson and Mayo 1991:141). These and other production problems were worked out in the course of 1940 and 1941. More difficult to resolve was the battle between the Quartermaster Corps and the Army Corps of Engineers over Army construction. The details of this conflict are beyond the scope of this work, but as a rule, the Quartermaster Corps had responsibility for most GOCO planning and supervision until December 1941; after 16 December, that responsibility was shouldered by the Army Corps of Engineers (Kane 1995:34-36; Thomson and Mayo 1991:110).

Another issue resolved during this period was the nature of the contracts between the government and the private operators at GOCO facilities. Fixed-price contracts were deemed too slow, and with the acceleration of events in Europe and East Asia, contracts based on cost-plus-fixed fee proved a better arrangement (Thomson and Mayo 1991:110).

Toward the end of 1941, the GOCO program was in full swing; it would be increased, but not greatly altered, in the months after the bombing of Pearl Harbor, when the United States entered the war directly. During peak war-time production, there were at least 77 GOCO industrial facilities in the United States (Kane 1995:1). Forty-three were "plants," where war materials were assembled; 35 were "works," where the basic materials were produced (Kane 1995:7-8).

Among the 35 GOCO works, at least 15 produced TNT, which remained a popular high-explosive throughout the war because of its availability (Green et al. 1990:366; Kane 1995:139). The operating contracts for the TNT plants usually went to established explosives companies, such as DuPont, Atlas, Hercules, and Trojan. With their operating staffs stretched thin, most of the contracts for auxiliary operations, such as the production of chemicals and loading operations, went to companies previously unfamiliar with ordnance work—the Quaker Oats Company, Sherwin-Williams Paint, and Procter and Gamble Soap, for example (Thomson and Mayo 1991:112).

Even though Holston produced high-explosives, it was not a typical high-explosives plant. Operated by Tennessee Eastman Company, a firm with no previous experience in munitions, it was one of the most expensive GOCO facilities ever built, and one of the last to be contracted and completed (Kane 1995:31; Thomson and Mayo 1991:111-112). The reason for this was the nature of the high-explosive produced at Holston—RDX and Composition B. Not only were these two substances powerful, but RDX and Composition B were recent developments, manufactured at Holston with previously untried production methods. All of this required months of experimentation in RDX and Composition B pilot plants before the Holston contract could be let in June of 1942. This experimentation is related in the following section.

Installation Preliminaries: Development of RDX and the TEC Pilot Plants

The development of RDX and Composition B began in Britain in the late 1930s in response to military intelligence that Hitler's new submarines were impervious to all but a direct hit with TNT. British scientists launched a feverish search for a more powerful high-explosive (MacDonald and Mack 1984:17). By 1938, their search led to the development of RDX (an acronym for Research Department Explosive). Technically, RDX was cyclotrimethylene-trinitramine, often abbreviated as "cyclonite" (Green et al. 1990:366).

RDX itself was not a new discovery. Known since 1899, cyclonite was formed by taking hexamine, a combination of formaldehyde and ammonia, and mixing it with nitric acid in a process then known as nitration, though now it is more commonly referred to as nitrolysis (Burton 1975:1-3; Kane 1995:137; Mills, personal communication 1995). Although cyclonite was known to be a powerful explosive with at least 30 percent more shattering power than TNT, it had little practical application for the simple reason that it was too sensitive. Detonated by even a light shock, it could not be melted or cast like the more versatile TNT (Burton 1975:1; HOW 1945a:II:8; Thomson and Mayo 1991:136).

In the late 1930s, the British discovered that RDX could be "tamed" by combining it with TNT and small amounts of wax. These combinations were referred to as "compositions." Composition A was 91 percent RDX and 9 percent beeswax, and could be press-loaded into artillery shells. Composition B was roughly a 60:40 mix of RDX and TNT (59.5 percent RDX, 39.5 percent TNT, and 1 percent beeswax), and was adequate for bombs. Composition C, preferred for demolition work, consisted of RDX mixed with 11.7 percent plasticizing oil (Green et al. 1990:366-367). In the late 1930s, Composition B was in greatest demand because it was the most promising mix for use against German U-boats.

By 1938, the British were producing RDX and Composition B at England's Woolwich Arsenal, believed to be the first successful RDX facility in the world (Burton 1975:2). British scientists and chemists produced RDX by nitrating hexamine, using the simple batch process. The nitration process required a tremendous quantity of undiluted nitric acid—11 pounds for every pound of RDX produced (MacDonald and Mack 1984:18). This costly and relatively slow process came to be known as the British or Woolwich Method.

The beginning of World War II in September of 1939 made the production of RDX all the more urgent. Despite the success of Woolwich Arsenal, fear of aerial bombardment forced the British to establish additional operations in Canada. By 1940, there was a small Canadian RDX plant near Shawinigan Falls, Quebec (Wolfe 1987:139). Neither facility could provide anything more than a fraction of the huge British demand for RDX.

The defeat of Allied armies in the Low Countries in May 1940, and the collapse of France in June, brought Winston Churchill to power and prompted a renewed determination in Britain to prosecute the war. After the summer of 1940, when the United States began actively aiding the Allied cause, there was closer cooperation between British and American ordnance scientists. On the American side, much of this cooperation was funneled through the National Defense Research Committee (NDRC), established by President Roosevelt in June of 1940. The NDRC was set up to mobilize the American scientific and academic community for a potential war effort, and one of the first projects was to capitalize on new British technological advances (MacDonald and Mack 1984:17). Foremost of these was RDX (HOW 1945a:II:8).

The NDRC interest in RDX led to the Tizard Mission, which brought British RDX technology and the Woolwich Method directly to the United States (Green et al. 1990:367). As a result, plans were instigated for the construction of the first RDX facility in the United States, the Wabash River Ordnance Works in Newport, Indiana. With construction commencing in May 1941, Wabash began production in November of 1942. Operated by DuPont under contract with the NDRC, Wabash produced RDX using the relatively slow and expensive Woolwich Method (Green et al. 1990:367; Kane 1995:92, 170; Thomson and Mayo 1991:136; Voigt 1945:312).

By late 1940, before construction began on Wabash, the British were urging the NDRC to find new and more efficient ways to produce RDX. The NDRC solicited the help of Dr. Werner E. Bachmann, a chemist at the University of Michigan, in November of 1940 (MacDonald and Mack 1984:18). By 1941, Bachmann had devised a better way to produce RDX. By almost all criteria, the "Bachmann Method," developed at the University of Michigan, was superior to both the older British Woolwich Method and the newer Canadian (Ross) Method that had been developed at Shawinigan Falls. The Woolwich Method required the nitration of hexamine with nitric acid, while the Ross Method was based on the nitration of formaldehyde with

ammonium nitrate (HOW 1944a:IV:62). By combining elements of both the Woolwich and Ross processes, Bachmann was able to nitrate hexamine through a mixture of undiluted (strong) nitric acid and ammonium nitrate. The resulting mixture was then dehydrated with acetic anhydride, which obviated the need for huge quantities of expensive nitric acid (Holston Defense Corporation c. 1991; Kane 1995:138; MacDonald and Mack 1984:18-19).

The tremendous advantage of the Bachmann Method was that it doubled the yield of RDX from hexamine, while at the same time reducing the quantity of nitric acid needed for the process by 85 percent (TEC 1942a:1). There were, however, still three potential problems. The first was time. The Bachmann process was slow, with two "wet" stages, and a drying stage in between (Wolfe 1987:139-140). The second problem was that a steady supply of acetic anhydride was required with the Bachmann Method to ensure that the RDX was properly dehydrated. The third issue was connected with acetic acid; one of the major by-products of the process was a great quantity of weak acetic acid, contaminated with RDX. In 1941, this was perhaps the greatest of the problems that surfaced at the various RDX labs and pilot plants sponsored by the NDRC (Burton 1975). In order to be used successfully on a large scale, the processing time with the Bachmann Method had to be hastened, a supply of acetic anhydride had to be available, and finally, a method for reclaiming both the acetic acid and RDX from the by-product had to be developed (Burton 1975; Caldwell 1988; Kane 1995:138; MacDonald and Mack 1984:18-19).

By the end of 1941, the NDRC and the Ordnance Department were interested in Kingsport as the potential answer to all of these problems. Not only did Kingsport have the necessary rail and highway connections, but it was also the site of the TEC, which was already known to prefer the continuous process in its manufacturing techniques, and had prior experience with both acetic acid and acetic anhydride, which were required for the production of Kodak's safety-film (Joe Davy, personal communication 1995; Kane 1995:138; Voigt 1945:133).

The TEC's lack of prior experience in ordnance production does not appear to have been a major concern to either the NDRC or the Ordnance Department. With the established explosives companies already overextended, the government had to look elsewhere if it was going to break new ground. If a company already demonstrated managerial ability, efficiency, integrity, and financial stability, the Ordnance Department believed that the rest could simply be learned (Thomson and Mayo 1991:113).

The NDRC and the Ordnance Department made first formal contact with TEC in early November of 1941, one month before Pearl Harbor. At that time, Major G. C. Tibbetts, Office of Chief of Ordnance, contracted with Perley S. Wilcox, president of TEC, to develop a process to recover, purify, and concentrate weak acetic acid, and convert it to acetic anhydride (Burton 1975:4; Holston Defense Corporation c. 1990:2; HOW 1942:1-2; Rotary Club 1946:195). The weak acid was to be provided by the government, and the first shipment arrived by train in stainless steel drums from Shawinigan Falls, Canada (HOW 1942:1-2; Johnson, interview 1995). At that time, TEC was not informed of the full nature of this work. In fact, TEC officials were shocked to learn that the weak acetic acid from Canada contained traces of RDX (Burton 1975:4).

Despite the surprise, the Acid Recovery Project began in November, under the direction of H. G. Stone, works manager of TEC. More closely associated with the project were C. C. Hyatt, Assistant Superintendent of Acids Division, and Cecil Dougherty of Cellulose Esters Analytical Laboratory (TEC 1942a:18). The work began in a small temporary lab in TEC Building 88 and was later moved to Building 96, the main TEC laboratory building (TEC 1942b). TEC reclaimed the first batch of pure acetic acid from the Canadian shipment on 16 December 1941 (Burton 1975:4), just nine days after the Japanese bombed Pearl Harbor.

With the entry of the United States into World War II, contact between TEC and the NDRC and the Ordnance Department increased exponentially as the need for RDX virtually exploded. In January 1942, German U-boats began sinking the American merchant marine at the rate of five to six ships per day, with

heavy losses along the Atlantic coast and among those ships in convoys to Britain (Caldwell 1988). The demand for RDX was unprecedented, but the supply was small. The Battle of the Atlantic, perhaps the most crucial period of the war for the Western Allies, extended from early 1942 to the late spring of 1943, when enough RDX was available to finally turn the tide against Germany's undersea fleet. The desperate need for RDX was never far from the minds of officials at TEC in the months after 21 January 1942, once Tennessee Eastman finally learned what the role of the company was to be.

On 21 January 1942, the NDRC contacted H. G. Stone, the TEC works manager, and told him they wanted a contract with Tennessee Eastman to produce RDX in an experimental pilot plant (Burton 1975:4; TEC 1942a:1). After laying out preliminary plans for an RDX pilot plant, TEC officials made a four-day trek (23-26 January) to visit NDRC officials in Washington, D.C., Dr. Bachmann's facilities at the University of Michigan, other facilities at the University of Illinois, and a Western Cartridge pilot plant in East Alton, Illinois. Headed up by H. G. Stone, the fast-moving TEC team included Fred R. Conklin, David C. Hull, and Lee G. Davy (Burton 1975:5; Crawford 1945; TEC 1942g:10).

In Washington, NDRC officials explained the three production methods then available for the manufacture of RDX and explained why they thought the Bachmann Method superior (TEC 1942a:1). It is believed that Dave Hull came up with the idea of a continuous reactor for the nitration of hexamine, based on the design of the Hershberg melting pot while in Ann Arbor (Wolfe 1987:141). Drawing on the TEC tradition of continuous process, the continuous reactor would later be an essential part of the Tennessee Eastman production of RDX.

After 21 January 1942, Tennessee Eastman became directly involved in the world of high-explosives. First came the contract for an RDX pilot plant, followed by another in February for a Composition B pilot plant. By the time both contracts (OEM 393 and OEM 397) were let in early 1942, the original acetic acid recovery project had been folded over into the new work, all funded through the NDRC (TEC 1942g:abstract). As fully explicated in the new contracts, TEC was to work on three goals: (1) establish a pilot plant for the manufacture of RDX based on the Bachmann Method; (2) develop the process and equipment needed for the recovery of acetic acid from the spent acid obtained from RDX manufacture; and (3) establish a pilot plant capable of mixing RDX with TNT to make the final product, Composition B (TEC 1942g:1).

Throughout the first half of 1942, TEC submitted regular reports to the NDRC, detailing progress toward these goals. The first of these reports dealt with the acid recovery project (TEC 1942b), while the five that followed covered RDX manufacture (TEC 1942a, 1942c, 1942d, 1942e, 1942f). A summary report (TEC 1942g) and a report on the Composition B incorporation results comprised the remaining reports (TEC 1942h). The acid recovery project has already been discussed; the RDX and Composition B pilot plants are discussed below.

Construction of the RDX pilot plant (also known as the RDX "semi-works") began the same day TEC officials left for Washington, D.C. Built between 23 January and 4 February 1942, the RDX pilot plant was constructed at Wexler Bend, along the north shore of the South Fork of the Holston River, near the southeast end of Long Island and immediately southeast of the main TEC complex. Although the Wexler Bend plant no longer exists, the site is located adjacent to the modern John B. Dennis Highway (Joe Davy, personal communication 1995; HOW 1944a:IV:63).

Long before RDX could be produced at Wexler Bend, there had to be numerous laboratory runs to work out chemical problems in the RDX process. RDX production began at the TEC laboratories by early February, with most of the work conducted in TEC Building 96, a three-story brick structure that already contained much of the acetic acid recovery equipment (Caldwell 1988; Crawford 1945; TEC 1942g:1, 48). There, work began on the RDX continuous reaction process, but the most immediate problem was training people to distinguish between stable and unstable RDX crystals, a distinction that had to be made before any production could occur. Teams of people with microscopes were trained to look for the unstable forms of

RDX. For reasons that were never fully understood, RDX production at the TEC labs, Wexler Bend, and later at Holston rarely produced any of the unstable variety of crystals (Caldwell 1988).

Constructed in late January and early February 1942, the Wexler Bend pilot plant consisted of 17 buildings (Rotary Club 1946:195-197). Most of these, especially the important production buildings, were identified by letters. Building A was a laboratory; Building B was the nitration building; washing occurred in Building C; and Building D served as the Wexler Bend magazine (TEC 1942g:10-12). After the first successful lab runs took place on 13 February, the Wexler Bend pilot plant itself was geared up for the production of RDX (HOW 1944a:IV:63). The sources vary as to when this took place, but all place it between 15 and 18 February (Crawford 1945; HOW 1944a:IV:63; TEC 1942g:1, 10). For the next three months, TEC officials worked feverishly to iron the kinks out of the Bachmann Method and make improvements of their own. Everyone seemed to share responsibility for this work, but, at least formally, there was a division of labor. Mechanical development and construction fell to E. G. Guenther; process development was the domain of Dave Hull; chemical development went to Lee Davy; operations was the purview of R. C. Burton; and H. G. Stone and Fred Conklin oversaw general management of the project (Burton 1975:5).

In order to employ the Bachmann Method, the RDX production process was divided into seven discrete segments: (1) the preparation of solutions; (2) nitration reaction; (3) reaction hold-up tank; (4) dilution and simmering; (5) draining and washing; (6) purification; and (7) grinding (TEC 1942e:1-8). The NDRC contract called for a Bachmann Method pilot plant, complete with a two-stage batch process, as worked out by Bachmann (Burton 1975:6). Bachmann himself visited the plant in February to oversee this work and conduct initial experiments (TEC 1942g:11).

Even though the Wexler Bend plant was constructed with a two-stage batch process, TEC officials quickly modified the plant to reflect their own preference for the continuous process (Burton 1975:6). The Bachmann formula (V86) called for the formation and isolation of an intermediate chemical, hexamine dinitrate, which was then nitrated to form RDX (TEC 1942g:1). TEC officials combined the Bachmann formula (V86) with one of their own (V129) to create a one-step process of continuous nitration, which was then followed by batch operations in the later steps of production (TEC 1942g:1). The entire process was ironed out by 6 April 1942, with the first successful run of RDX, using the new and improved method (Burton 1975:6).

The TEC continued modifications to the Bachman process to improve the efficiency and safety of RDX production. A two-stage nitration process was replaced by a more efficient continuous reaction. In addition, RDX was kept in solution throughout the process, making it possible to pipe the explosive in slurry form to different production areas by way of centrifugal pumps, rather than being loaded and handled in solid form, which was both dangerous and time-consuming (Burton 1975:6; Crawford 1945).

The TEC also applied a chemical identification system that would improve the safety and security associated with RDX production. Long before the war, TEC used three-digit numbers to identify the chemicals used in its various processes. This proved to be safer than using complicated chemical names and abbreviations around a work force that often had a limited education in chemistry (Herring, interview 1995). After the Japanese attack on Pearl Harbor, the numbers also served as an additional security measure. Hexamine, for example was designated "501"; nitric acid, depending on its specific gravity, was either 502 or 503; ammonium nitrate was 504; hexamine dinitrate was 505; and RDX was 506. Other commonly used chemicals were (TEC 1942g:4):

acetic anhydride	509
glacial acetic acid	521
dilute acetic acid recovered from RDX production	522
TNT	599
beeswax	598

This practice would later be employed at Holston, both for the identification of chemicals, and for the areas set aside for their treatment and production.

On 6 February 1942, two months before Wexler Bend went on line, TEC agreed to build another "semi-works," the Horse Creek pilot plant, for the incorporation of RDX with TNT to form Composition B. Located across the Holston River from the main TEC complex, Horse Creek sat beside an old logging railroad at the foot of Bays Mountain, about a mile west of the river (Burton 1975:6; Joe Davy, personal communication 1995; Wolfe 1987:142).

Construction of the Horse Creek pilot plant began on 17 February and was completed by 27 February (Crawford 1945). While the innovations in this plant were not as radical as those in the RDX facility, they were still important. In March, TEC officials visited DuPont's Eastern Laboratories in Gibbstown, New Jersey, to study the machinery needed to grind RDX. Throughout March, there were frequent meetings between TEC officials and representatives from both DuPont and the NDRC for discussions on such matters as temperature control and safety measures. That same month, the first shipment of TNT reached Horse Creek, ready for incorporation with Wexler Bend's RDX (TEC 1942c:32-39, 1942g:12). The first Composition B was produced at Horse Creek on 7 April 1942 (Crawford 1945; Voigt 1945:132), but experimentation continued on the final assembly line.

The greatest TEC innovation at Horse Creek was in the final casting process for Composition B. DuPont, and the British before them, had used the "cake" casting method, which produced a thick sheet of Composition B, which then had to be dried and cut or ground into smaller pieces. This was time-consuming and dangerous because it exposed workers to poisonous TNT fumes for long periods of time (Burton 1975:7; TEC 1942d:29-30). In April, TEC officials devised a method of extruding small globules of Composition B, which would then land on a final conveyor belt and quickly dry in a form that resembled the popular chocolate "Hershey Kisses." These pellets, dubbed "Jap Kisses" by pilot plant employees, had their first successful run on 21 April 1942 (Burton 1975:7; Crawford 1945; HOW 1944a:IV:63). With the final elaboration of the pellet process, TEC had turned the Bachmann laboratory process into an industrial assembly line. It was one of the most remarkable ordnance achievements of World War II, and TEC had accomplished this in exactly three months.

Throughout this early period of the war, there was a constant demand for more RDX, and it was soon apparent that the TEC pilot plants were dress rehearsals for a much larger facility. On 27 April 1942, just two days after the first load of Composition B was shipped out, TEC officials went to Washington, D.C. for a crucial meeting with representatives of the NDRC, Ordnance, and DuPont. The meeting was held to discuss the best method for producing massive amounts of RDX, and recommendations were solicited from TEC. At the meeting, H. G. Stone suggested that any future operation should make use of the continuous reactor (nitration) process, followed by simmer, wash, purification, and grinding procedures conducted by batch techniques. Some DuPont representatives raised objections to the TEC continuous feed method, and the NDRC decided that additional experimentation should take place before final decisions were made (TEC 1942d:34-39).

Just three days later, on 30 April 1942, TEC submitted its formal report on the pilot plant operations to the NDRC and presented plans for the creation of a large commercial facility to begin RDX production (HOW 1944a:IV:63). During the following month of May, Army Ordnance evaluated these plans (Burton 1975:7). Simultaneously, samples of the RDX were submitted to the Explosive Research Laboratory of the U.S. Army (TEC 1942d:40). On 6 May 1942, TEC received permission to increase pilot plant production of both RDX and Composition B (HOW 1944a:IV:63).

Even though the Wexler Bend and Horse Creek pilot plants were test runs for a larger facility, they still produced RDX and Composition B, and did so long before Holston Ordnance Works became operational. On 25 April 1942, the first shipment of Composition B left the Horse Creek pilot plant for the U.S. Naval

Mine Depot in Yorktown, Virginia (Crawford 1945). Soon, Wexler Bend was producing two pounds of RDX per minute with an average daily production of approximately 2,500 pounds (TEC 1942g:abstract). As the RDX was shipped to Horse Creek, that facility began the production of Composition B, with an average daily capacity of 4,500 pounds. By early August 1942, total Composition B production at Horse Creek approximated 221,000 pounds (TEC 1942g:abstract).

The Composition B produced at the TEC pilot plants was so valuable that trains shipped the material to naval ordnance depots without even waiting for a full load. Composition B was put into aerial bombs and depth charges for use in the war against German U-boats. During this period, air patrols normally jettisoned unused TNT bombs over water as a safety precaution before landing, but RDX was too valuable to waste, so pilots were instructed to return with all unused RDX bombs (Joe Davy, personal communication 1995).

The scarcity of RDX led to an innovation in the anti-submarine campaign. Rather than putting the valuable explosive in a traditional depth-charge the size of a drum, which could only cover a small area, it was divided into small "hedgehog missiles." Each missile was about the size of a coconut with a load of only 18 pounds of Composition B. These small depth-charges were then broadcast 50 or so at a time over a wide area, shotgun-style. Rather than detonating at a certain depth, they only exploded if they hit metal. A U-boat crew might not know it was being hunted until RDX blew a hole in its hull (Caldwell 1988; Crawford 1945; Herring, interview 1995).

The demand for RDX was so great that there was little time between completion of the pilot plants and the order to begin construction of the massive facility that was soon known as Holston Ordnance Works. There was little doubt that TEC would be selected to run the new facility. Ordnance made the decision in late May, and TEC had the contract in early June 1942 (Englander 1946:15-16). Work on Holston began in the summer of 1942, with the first production of Composition B rolling off the lines in early May of 1943. In the days that followed, Wexler Bend and Horse Creek were quickly overshadowed by the larger and more efficient Holston, but this should not detract from the achievements of the pilot plants. Without Wexler Bend and Horse Creek, there would have been no Holston, and certainly no continuous reaction process (Report on Administrative Problems 1945:1). On 9 October 1942, management of the pilot plant operations was shifted from the NDRC to the Ordnance Department. In the months that followed, as Holston neared completion, the pilot plants served as Holston training facilities (Crawford 1945). After Holston began production in early May of 1943, the pilot plants became redundant and were quickly closed. Horse Creek was shut down on 10 May 1943 (HOW 1943b:V:1); Wexler Bend was shut down 11 days later (Holston Defense Corporation c. 1990:2). On 6 August 1943, the original NDRC contracts for the pilot plants were terminated. By that time, Holston Ordnance Works was in full operation (Voigt 1945:133-134).

HOLSTON ORDNANCE WORKS: DESIGN AND CONSTRUCTION

The Contracts

Contract negotiations for the big RDX and Composition B manufacturing facility known as Holston Ordnance Works began on 4 May 1942. Throughout this period, it was understood that the new facility would produce RDX in accord with the Bachmann Method as elaborated by the TEC pilot plants. By the end of May and the beginning of June, letters of intent were sent out to the various firms that would design, construct, and operate the new facility. These letters allowed work to begin and were followed by formal contracts.

On 29 May 1942, letters were issued to both Charles T. Main, Inc., of Boston, and Fraser-Brace Engineering Company, Inc., of New York. These companies would serve as facility architect-engineers and architect-engineer-construction-managers, respectively (Englander 1946:15). On 6 June, a similar letter was sent to TEC, selected as the facility operator and design consultants (HOW 1942:6, 1944b:IV:63). In each

case, it was specified that the new RDX facility should have a daily capacity of 170 tons, with construction work slotted to begin immediately (HOW 1944a:IV:63).

Because of the relatively experimental nature of the new facility, the design and construction of Holston required the close cooperation of all the participants. In many cases, design, construction, and production occurred almost simultaneously (Englander 1946:15). June 1942 was a particularly crucial month, as representatives of all three companies converged on the site to begin work on the new facility. Overseeing this work were representatives from the Ordnance Department and the Construction Branch of the Army Corps of Engineers (Englander 1946:18).

In June, when the first contracts were signed, the duties of each company were enumerated. Charles T. Main, Inc., was to develop the designs and specifications outlined by TEC in drawing up plans for the manufacturing buildings. It was also responsible for the design and specifications of all other facilities, including building layout and the overall coordinate system. Charles T. Main was also responsible for the inspection and quality control of building materials, and the inspection of all construction work done to their specifications (Englander 1946:18-19).

Fraser-Brace Engineering Company, Inc. (Fraser-Brace), was chosen for the construction work because it had previous experience with building large-scale chemical and ordnance facilities, such as the Weldon Springs Ordnance Works which was one of the largest TNT plants in the world at that time. Fraser-Brace was also familiar with construction operations in which design and construction work went hand-in-hand. According to the formal division of labor, Fraser-Brace was responsible for the construction and general construction management of the facility. It was also charged with the procurement of all materials, except manufacturing equipment, plus the design and layout of all temporary buildings, utilities, and construction facilities (Englander 1946:19).

The Construction Branch of the Army Corps of Engineers was brought in to supervise and inspect the design and construction work of Charles. T. Main, Inc., and Fraser-Brace. Because of the size and importance of the project, a special Corps jurisdiction, Holston District, was created and placed under the Ohio River Division (Englander 1946:18).

TEC was responsible for the general layout of the plant, design of the manufacturing buildings, and design and procurement of all process equipment. When all this was complete, TEC would run the facility—a 10-line production plant that would make RDX, and combine it with TNT to create Composition B (Englander 1946:18; Report on Administrative Problems 1945:1). The new facility was to be called "Holston Ordnance Works," often shortened to HOW, and TEC was to run the plant through a subsidiary organization known by the same name (Englander 1946:18).

In August 1942, two months after work began, formal contracts were drawn up between the Army Corps of Engineers and both Charles T. Main, Inc., and Fraser-Brace for the design and construction of Holston Ordnance Works. These contracts specified that the completion date would be August of 1943 (Englander 1946:15). The Fraser-Brace contract, No. W-1911-ENG-1, was a fixed-fee architect-engineer-manager (AEM) contract (Englander 1946:19; Holston Defense Corporation 1963:9), and it is presumed that Charles T. Main, Inc.'s contract was similar. Tennessee Eastman operated under Contract No. W-648-ORD-705, a fixed-fee agreement with the Ordnance Department (Englander 1946:18; Voigt 1945:132). It was about this time, on 9 August 1942, that the NDRC relinquished its control of the TEC pilot plants to the Ordnance Department (HOW 1944a:IV:63).

Plant Design

Rough plant designs for Holston Ordnance Works were probably well underway by the time Charles T. Main, Inc., Fraser-Brace, and Tennessee Eastman received their letters of intent. As early as December of 1941, the War Department had drawn up a "Confidential Site Survey for an Ordnance Plant near Kingsport, Tennessee" (Englander 1946:15). Despite these preparations, however, recent developments in the TEC pilot plants precluded any but the most general designs and layouts for the new RDX plant by the time construction work commenced in June and July.

The revolutionary nature of the new facility demanded that the three main contractors work together, especially in the opening months of construction. Engineering and design work had to begin with Tennessee Eastman, since only TEC engineers knew how Holston had to be arranged in order to produce RDX by using the continuous feed process. To this end, some 87 TEC engineers and draftsmen began work on the 6,000+ engineering drawings required to put Holston Ordnance Works on paper (Burton 1975:7). This work was supervised by many of the same people who would later supervise Holston itself—H. G. Stone, Fred R. Conklin, L. G. Haller, R. C. Burton, E. G. Guenther, and, on loan from Eastman headquarters in New York, Carey H. Brown. Soon, this drafting operation was moved to the Kingsport Civic Auditorium, which served as a temporary home for the administration of Holston (Burton 1975:7; Crawford 1945). As a result of this initial work, Tennessee Eastman had a significant influence on the new facility. Holston resembled Tennessee Eastman not only in personnel and procedures, but in architectural design as well.

TEC plans for Holston Ordnance Works required that the facility be laid out in two discrete areas or plants. Area A, or Plant A as it is sometimes called, was to produce the acetic acid and acetic anhydride necessary for RDX production. Area B, or Plant B, was much larger and contained 10 RDX production lines, an administrative area, and extensive magazines (Figure 5).

Area A, comprised of 45 acres, was sited along the north shore of the South Fork of the Holston River, immediately northwest of the Tennessee Eastman complex (Englander 1946:16-17). It was devoted to the manufacture of glacial acetic acid and acetic anhydride, two chemicals essential for the Bachmann process and long familiar to TEC personnel. It was probably for proprietary reasons that Tennessee Eastman kept Area A close at hand.

On the other hand, it was probably for safety reasons that Area B was placed at a distance. Located four miles west of Area A and three miles west of Kingsport, Area B stood just below the confluence of the North and South forks of the Holston River. Reduced to 5,912 acres, Area B originally contained some 6,370 acres (Holston Defense Corporation c. 1990:4; MacDonald and Mack 1984:22). Area B was divided into two sections—the main manufacturing plant and the main magazine area. The Holston River separated these two sections (Englander 1946:17).

Areas A and B were connected by an interplant railroad system with 29 miles of track. Interplant lines took spent acetic acid from Area B to Area A, and brought glacial acetic acid and acetic anhydride from Area A to Area B (Johnson, interview 1995). In addition, Area A was tied to the Clinchfield Railroad line, while Area B had connections with the Southern Railroad line (HOW 1945b:II).

The interactive processes involved in the operation of Areas A and B will be explored in greater detail in the Contractor Operations and the Technology sections of this chapter. Only brief mention will be made here of the main buildings designed for Areas A and B. In Area A, the most important buildings were related to the production of acetic anhydride, which was distilled from acetic acid (MacDonald and Mack 1984:33). These buildings included the acetic acid concentration plant (Building 2), the acetic acid production plant (Building 3), the acetic acid catalyst building (Building 4), the refrigeration plant (Building 5), the acetic anhydride refining plant (Building 6), and the two acetic anhydride production plants (Buildings 7 and 20). In addition to these prime buildings were a number of essential support facilities: administration and

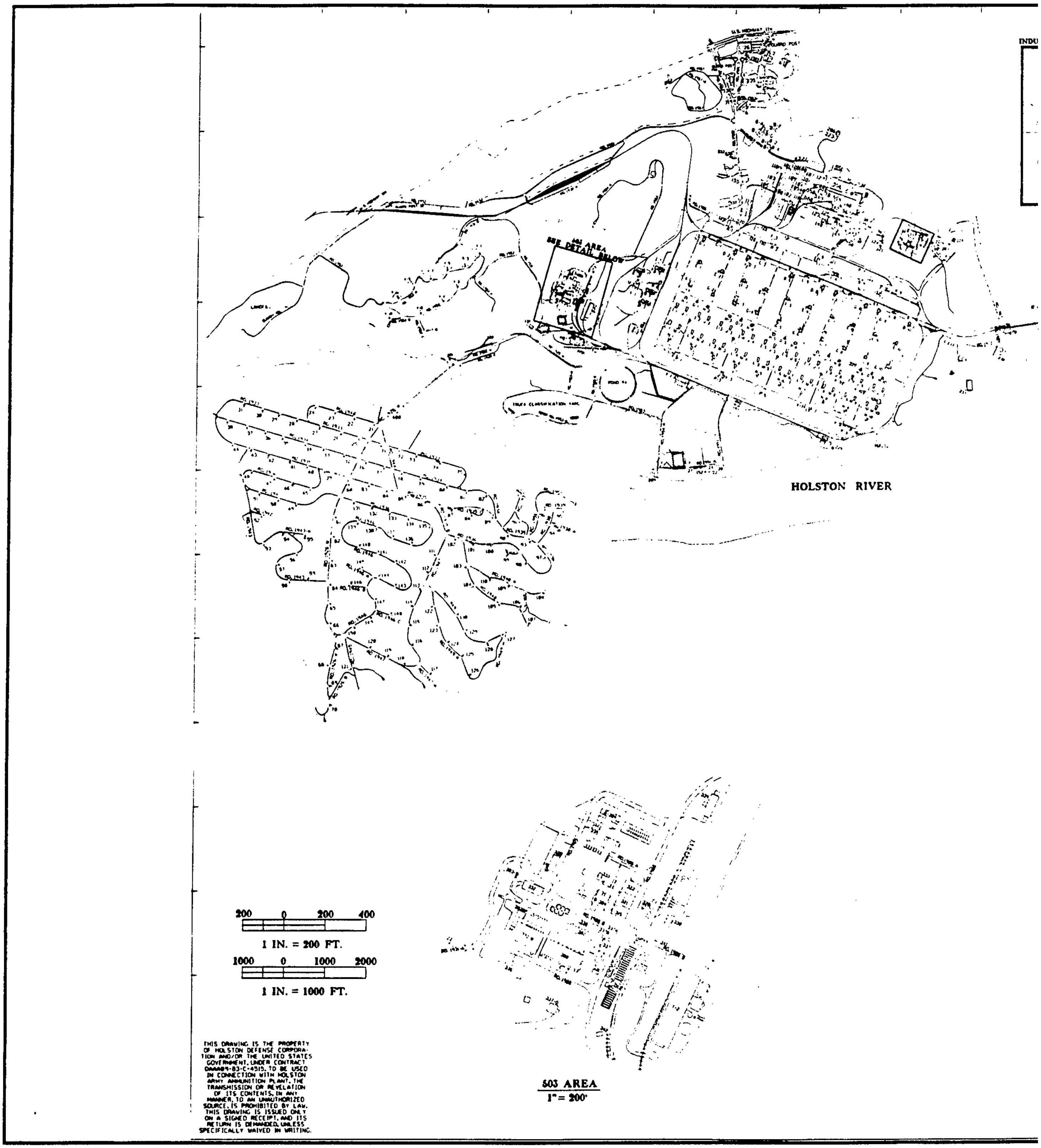


Figure 5. Layout of Holston Ordnance Works (taken from Building Location Plan, Area A and B, 1992).

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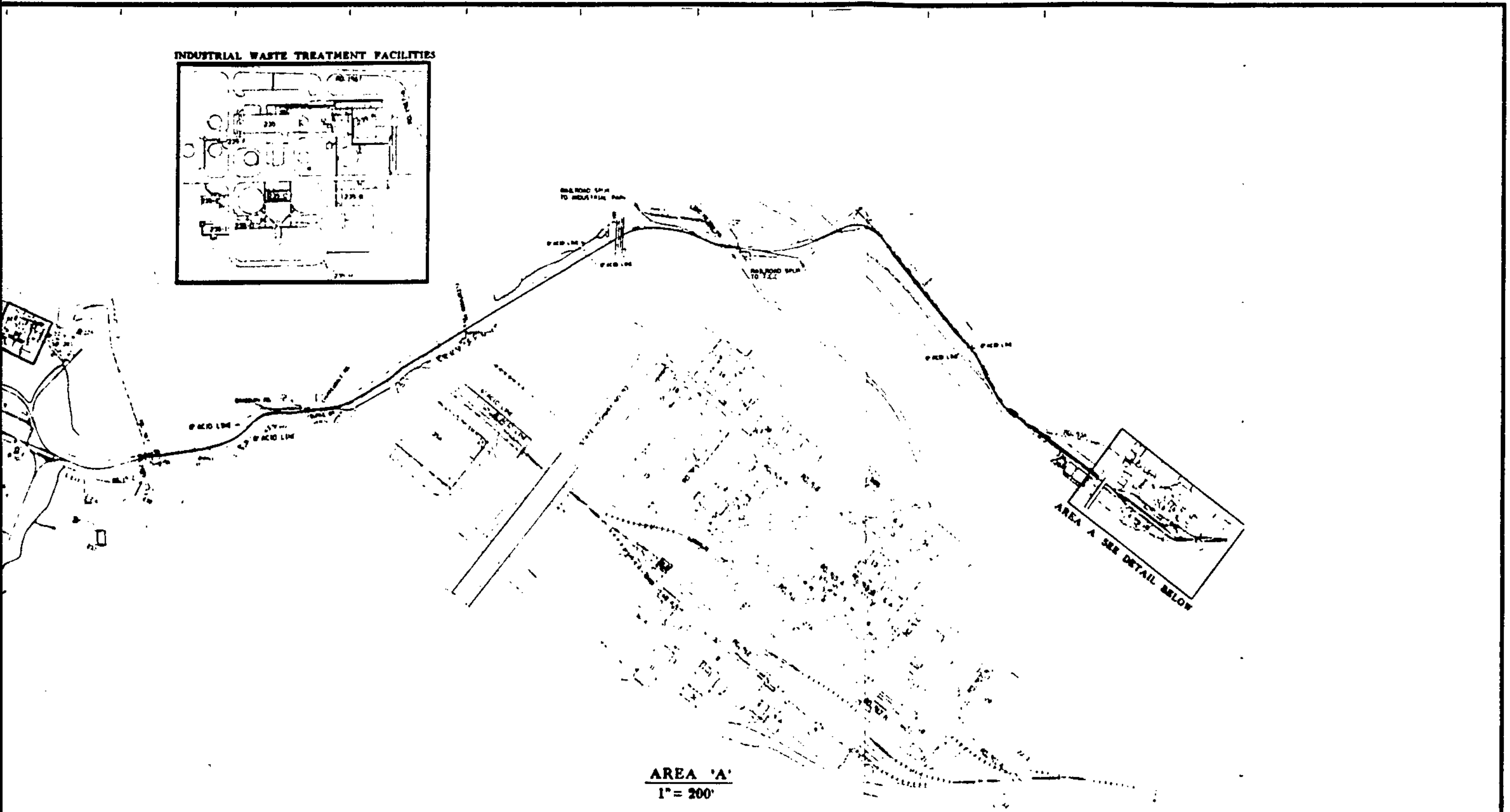

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APPROVED	RAC	

HOLSTON ARMY AMMUNITION PLANT
HOLSTON DEFENSE CORPORATION
KINGSPORT, TENNESSEE

BUILDING LOCATION PLAN
AREA A & B

SHEET NO.				DRAWING NUMBER
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laboratory (Building 1), steam plant (Building 8), and Building 10, the producer gas plant, which supplied the energy for the acetic anhydride manufacturing process (Historic American Engineering Record TN-10, 1986; MacDonald and Mack 1984:22-25).

Area B was larger in size than Area A, with a great many more auxiliary buildings. Both in design, and later in operation, the work associated with Area B revolved around the production lines which were numbered one through 10 from west to east. The lines were paired, one and two, three and four, etc., with even-numbered lines laid out as mirror-images of the odd-numbered lines (Miller, personal communication 1995). In this fashion, some single buildings could be placed between the two lines and serve both.

While production lines were numbered, each building along the production line was identified by letter. The major steps in the RDX and Composition B process occurred in buildings C, D, E, G, H, I, J, L, M, and N. The C buildings were the staging area for the initial RDX process. Crude RDX was formed in the D buildings as a result of the nitration process; the RDX was then pumped to the E buildings, where it was washed. Spent acetic acid tainted with RDX was then pumped to the B buildings, all located immediately west of the first production line. The B buildings recovered acetic acid (sent back to Area A) and the residual RDX was returned to the E buildings.

From the E buildings, the steps to produce RDX continued to shift from building to building, but the chain followed a more direct path. RDX was pumped to the G buildings for purification and recrystallization, and then to the H buildings for dewatering. After that, RDX was incorporated with TNT in the I, J, L, and M buildings before it was prepared for loading in the N buildings. Just before incorporation, RDX was in dry form and was particularly dangerous. Thus, extensive barricades were placed around these buildings along with wooden catwalks between the buildings to protect the RDX from the elements.

West of the B buildings, but still close to the production lines, was the 503 Area or nitric acid area, which supplied nitric acid to the C buildings. Because TEC did not have prior expertise in the production or use of nitric acid, the designs for this segment of the facility were copied from DuPont and the Hercules Powder Company (Burton 1975:7).

Other sections of Area B included the shop area immediately north of the production lines; the administrative area to the north-northwest of the shops and adjacent to U.S. Highway 11-W; and the steam plant (Building 200), located immediately south of the 503 Area. In addition, there was a storage area for ammonium nitrate, located west of the 503 Area, which contained 11 above-ground Richmond-type magazines (Figure 6). There was also the main magazine area for RDX and Composition B on the other side of the Holston River that contained 130 earth-sheltered, Corbetta-type beehive magazines (Figures 7 and 8; MacDonald and Mack 1984:25-28).

Main Construction Phase

As soon as plans could be drawn, Charles T. Main, Inc., and Fraser-Brace began turning plans into construction. The main building phase at Holston lasted almost one year, from 6 June 1942 to 8 May 1943 (Rotary Club 1946:197). In addition to constructing the main facilities at Holston, Fraser-Brace also had to build or refurbish a number of temporary facilities needed to accommodate the construction work.

While TEC planners and Ordnance personnel were temporarily located in the Kingsport Civic Auditorium, Fraser-Brace located its temporary quarters at the Kingsport Junior High School, one mile from Area A (Report on Administrative Problems 1945:1). There, AEM personnel and Army Corps of Engineers officials worked out initial construction details during the first two-and-one-half months of the project.

Figure 6. Gravity Type (Richmond) Magazine for Ammonium Nitrate, Area B (courtesy of Holston AAP Photo Set No. 39-B [on file Engineering Vault, Building 26]).

Figure 7. Raised-Type Corbetta Magazine, Area B (courtesy of Holston AAP Photo Set No. 38-B [on file Engineering Vault, Building 26]).

Figure 8. Flat-Type Corbetta Magazine, Area B (courtesy of Holston AAP Photo Set No. 38-B [on file Engineering Vault, Building 26]).

Fraser-Brace's first permanent personnel office was established in downtown Kingsport and served as liaison with the U.S. Employment Service and the War Manpower Commission (Englander 1946:17). After field surveys began in June, the field engineer's office was set up at a rural schoolhouse on the site of Area B until the Area B administrative area could be completed (Englander 1946:17). Another top priority was the drilling of water wells to provide water for workers and staff at Area B (Area A relied on Kingsport municipal water) (HOW 1943a:X:18). Even though most workers provided their own housing in Kingsport and vicinity, a few barracks were erected for construction workers.

Most of the construction of Holston took place in the fall of 1942 and the winter of 1942-1943. During this time, construction employment peaked at between 15,000 to 18,000 workers. Work on Area A progressed faster than in Area B, which was only 85 percent complete by February 1943 (HOW 1943c:13-16, 1944b:IV:63). Both areas, however, had their own set of construction problems. Progress in Area A was slowed by the discovery of explosives and acids that had been buried at the site by local munitions factories after World War I. In addition to TNT, the ground was contaminated with some 54,000 pounds of picric acid. The situation was considered so serious that the Holston River was diverted to wash over the contaminated area and flush the acid downstream. This was done only after grudging approval was obtained from local TVA officials (Doerr 1945:2-9).

Even more serious for the timetable at Area B were the winter weather conditions of 1942-1943. Rain was a constant problem, and Area B became a veritable sea of mud (Crawford 1945). Stories are still told of large machines that sank to unrecoverable depths and were simply buried.

The greatest problem, for both Areas A and B, was the perennial shortage of construction materials created by the war. Well before the end of 1942, the federal government had rationed all materials needed for the war effort. The private use of copper, steel, and aluminum, among other things, was almost completely halted. Most wartime construction relied on wood, concrete, and even brick. The use of other materials had to be approved.

Despite the importance of RDX to the war effort, Holston had some difficulty getting top clearance for material acquisition during the early stages of construction. This was due to fierce competition between vital industries more than bureaucratic oversight. One story that made the rounds concerned an aluminum pipe that was held up in delivery. Told that the item would be delivered in a week, H. G. Stone, Holston general works manager, is said to have retorted, "the Japs took Manila in a week!" The part arrived the next day. Unfortunately, most other requisition problems could not be resolved so easily and shipments of copper, aluminum, and stainless steel rarely arrived on time (Report on Administrative Problems 1945:1; Voigt 1945:133-134).

It was not until 23 December 1942 that Holston received the "AAA" high priority rating for war materials. Even then, there were recurring problems in obtaining the necessary equipment for the plant facilities (Voigt 1945:133-134). These delays were so severe that the original dates set for completion of construction and beginning of production (15 February 1943 for Area A and 7 March 1943 for Area B) had to be pushed back (HOW 1943c:1-2). It was two months later that RDX production began at Holston Ordnance Works.

With the possible exception of the barracks, which no longer exist, there is no indication that Fraser-Brace made use of the Army's temporary mobilization architectural plans available during World War II. Undoubtedly, the experimental nature of the RDX facility made it necessary for TEC and Fraser-Brace to work from plans that were relatively unique. This was even true in the choice of building materials. Unable to use structural steel for the critical production line buildings, TEC designed buildings supported by reinforced concrete pillars. Normally, such construction would have been framed with wood during World War II, since this was the cheapest building material available. In the case of Holston, however, the reinforced concrete pillars were often walled with brick, which was both cheap and plentiful in Kingsport (Johnson, interview 1995).

After a number of delays, the first trial run of an RDX production line began on 29 April 1943. On 8 May 1943, production line 1 became the first at Holston to go into full production (HOW 1945a:II:4). The other nine lines followed that same month and throughout the summer and fall of 1943. This marked the end of the main construction phase at Holston and the beginning of the production phase. It did not, however, mark the end of construction, for Holston was soon ordered to increase facilities to allow for a 100 percent production increase.

Continuation of Construction

In May 1943, the first month of RDX manufacture, the Army requested that the Ordnance Department increase production levels at Holston well above the amounts called for in the original contracts. The TEC and Holston officials had just discovered that with only moderate adjustments to the existing plant, the production of RDX could be substantially increased.

The first increase was decided upon in June, and on 14 July 1943, the Ordnance Department authorized the expansion of Holston production from 170 tons of RDX a day, as called for in the original specifications, to 240 tons. This necessitated an increase in Composition B from 283 to 400 tons a day. On 27 July, RDX production was raised from 240 to 340 tons a day, with a commensurate increase in the production of Composition B. This was a full 100 percent increase in the production of RDX from that specified in the original agreements (Hardy 1943; Wolfe 1987:144).

Supplemental contracts were let in the summer of 1943 to allow for this increase, with the new work scheduled for completion set at mid-March 1944 (Englander 1946:15). Along each production line, a new ammonia oxidation unit, a new boiler, and adjustments to the D buildings (nitration) were added (Hardy 1943). Additional structures were also added in the B building area (HOW 1944b:XIII:41). The first four production lines went on 200 percent production in November 1943, three more went on in December, while the last three increased production in January of 1944 (Englander 1946:15). By early February 1944, all construction was completed, more than a month ahead of schedule (Englander 1946:15; HOW 1945a:II:4; Rotary Club 1946:197).

In March of 1944, with construction completed and all buildings under the management of plant operators, the Army Corps of Engineers made a final inventory of Holston Ordnance Works. A total of 610 buildings had been constructed—48 in Area A and 562 in Area B (MacDonald and Mack 1984:22-25). The total cost of this construction reached $128,681,202 (Voigt 1945:133). Holston had become one of the most expensive GOCO facilities built during World War II.

CONTRACTOR OPERATIONS

Mission and Production

Production line 1 made its first trial run on 29 April 1943, and geared up for regular production on 8 May 1943. Production line 2 followed suit on 27 May, followed by line 3 (12 June), line 4 (1 July), and line 5 (11 July) (HOW 1944a:IV:63). By September, there were seven lines in operation (HOW 1943d:IX:1). The eighth line was opened on 7 October 1943 (HOW 1943a:X:2). By December, all 10 lines were in production (HOW 1943a:XIII:3), but to complicate matters the lines were also being reworked to permit a doubling of production during most of this period. All construction work was finally complete in February of 1944, with Fraser-Brace bowing out in March. In the year and a half that remained of the war, the facility would be the sole responsibility of Holston, a subsidiary of Tennessee Eastman.

The main mission of Holston Ordnance Works was to produce as much RDX and Composition B as possible, and to make it as quickly as possible. Holston operated 24 hours a day, seven days a week. In order to keep the production lines supplied with materials, the interplant railroad made trips between Areas A and B every four hours (HOW 1943d:IX:8).

In order to carry out its mission, Holston either had to produce or arrange for the supply of the chemicals essential to the Bachmann process, i.e., hexamine, acetic acid, acetic anhydride, ammonium nitrate, nitric acid, and acetone (HOW 1944c:X:56; MacDonald and Mack 1984:4). Glacial acetic acid and acetic anhydride, specialties of Tennessee Eastman, were made in Area A. Most of the other materials had to be brought in. Hexamine, the stock from which RDX was made, was supplied by the Morgantown and Cherokee Ordnance Works (Thomson and Mayo 1991:136). Holston required almost one-half million pounds of ammonium nitrate each day, and in the first months of operation, that material was brought in from plants in Louisiana and Kansas (Burton and McNeeley 1944:20). Later, ammonium nitrate would actually be manufactured at Holston. To ensure smooth operation, production was organized into seven departments that were responsible for the various materials manufactured or used at Holston Ordnance Works (HOW 1944c:X:45-53). These seven departments included the:

RDX Department
Composition B Department
Explosives Stores Department
Primary Distillation Department
Acetic Acid Recovery
Nitrates Recovery
Ammonia Recovery
Acid Concentration Department
Acetic Acid Department
Acetic Anhydride Department

Administrative Staff

Heading up these departments, and indeed all of Holston, were two parallel commands. The first was the contractor-operator administration of Holston, largely supplied by Tennessee Eastman. For most of the operating period, this staff consisted of the following personnel:

Herb G. Stone, Works Manager
Carey H. Brown, Assistant Works Manager
Philip Farnham, Executive Assistant to Works Manager and Superintendent, Industrial Relations
R. C. Burton, General Superintendent of Production
R. S. Leonard, Office Manager
L. G. Haller, Chief Engineer
Ed G. Guenther, Superintendent Explosive Division
R. S. Saunders, Superintendent, Plant A
Lee G. Davy, Superintendent, Chemical Control
J. C. Cox, Superintendent, Shops and Maintenance

The only change to occur was on 15 June 1944, when Herb Stone was transferred to other war work and Carey Brown took his place. Brown remained in this position until the end of the war (HOW 1944a:VI:5, 1944c:X:6).

Formally in charge, but only indirectly involved in production, was the second command, provided by the Ordnance Department. During World War II, the commanding officers at Holston Ordnance Works were (Holston Defense Corporation 1963:4; Voigt 1945:134):

Lt. Col. William E. Ryan, June 1942 - April 1944
Lt. Col. F. R. Scherer, April 1944 - April 1945
Lt. Col. John W. Quillen, April 1945 - May 1946

The operation of Holston was extremely complicated, and it took between 5,000 and 7,000 people to ensure the smooth operation of the production lines and the various support facilities (a more detailed discussion of employment figures and demographics is presented in the Social History section of this report). A considerable amount of initial training was required before workers could operate their stations. In 1942 and early 1943, workers assigned to Area B were trained at the TEC pilot plants. Their counterparts in Area A were trained directly at the Tennessee Eastman complex (HOW 1942:16). On 10 May 1943, after the first production line went into operation, the Horse Creek pilot plant was closed down and its personnel transferred to the Composition B Department of Holston (HOW 1943b:V:1). Wexler Bend followed suit on 21 May 1943 (Holston Defense Corporation c. 1990:2).

Administrative Problems

Operations at Holston Ordnance Works ran smoothly. No fatalities occurred as a result of mishandling explosives and Holston set records for RDX and Composition B production. Despite this achievement, there were a number of administrative problems, most of which were outlined in a report compiled near the end of the war by Holston Ordnance Works and Tennessee Eastman, and entitled *Report on Administrative Problems* (1945). These problems can be divided into three groups: problems that arose with the government contract; personnel and morale problems; and problems associated with the dual command structure.

Even though the report did not go into specifics, it was clear that operating from the official War Department guide, "Ordnance Procurement Instructions," was difficult. This was particularly true in the case of a cost-plus-fixed-fee contract, like those that governed most GOCO facilities. Due to the special nature of the work at Holston, it was often necessary to have extra or "late" construction projects. In those cases, the contract called for all additional work to be approved through the War Department in Washington, D.C. To further complicate matters, all work over $2,000 had to be awarded to outside firms, which often proved to be both costly and slow (Report on Administrative Problems 1945:16, 14-15).

From all indications, it was never a substantial problem to keep Holston staffed with workers, but it was difficult to keep some of them out of the draft. The Tennessee State Selective Service organization recommended Holston for special status, but local draft boards were under no compulsion to act on that recommendation. Holston had to deal with 176 different local boards in order to keep key personnel on the production lines (Report on Administrative Problems 1945:6-7).

Another problem was wage-rates. Holston adopted the TEC practice of basing wages on competence and performance evaluation. This proved to be difficult to administer in war-time and led to hard feelings on the assembly line. Although the TEC method was never changed, by the end of the war, a flat rate or a rate based on simple seniority was instituted to administer wages (Report on Administrative Problems 1945:9).

Food arrangements were problematic in Area B, where personnel were widely dispersed. There, food was originally provided through concessionaires who were established in one main cafeteria and in several widely scattered canteens. Many of the canteens, however, were so poorly run that Holston finally had to eliminate

the concessions altogether and directly operate the food facilities (Report on Administrative Problems 1945:10).

The dual nature of the command structure at Holston brought its share of problems. Both Holston and Ordnance shared responsibility for security at Holston, which contained thousands of workers and millions of dollars worth of military equipment. To guard this ordnance facility, there were two protective fences around Area B and some 450 security guards, some of whom answered to Holston while others answered to Ordnance. This led to considerable friction between the two commands (Report on Administrative Problems 1945:2-4).

Final Production Figures

RDX and Composition B were produced at only two plants during World War II—Wabash River Ordnance Works and Holston Ordnance Works (Kane 1995:91). The difference between these two, however, could not have been greater. Wabash, using the older Woolwich Method, could not compete with Holston's improved Bachmann Method and the continuous feed process. It has been estimated that Holston produced 90 percent of the Composition B manufactured in this country during war-time (Historic American Engineering Record TN-10, 1986:1). Even in June of 1944, on the occasion of the departure of H. G. Stone, Ordnance officials proclaimed Holston "the largest known producer of RDX in the world" (HOW 1944a:VI:5). By 1945, the average daily rate of Composition B production was close to 700 tons. In May of that year, production reached a peak of nearly 750 tons (1,500,000 pounds) per day, with an average monthly figure of 27 million pounds (Crawford 1945; Englander 1946:16; Thomson and Mayo 1991:136). Every day Composition B was packed into 30,000 boxes and sent to five Navy and four Army loading plants (Crawford 1945). Even at this rate of production, the demand for RDX and Composition B was so great that the Holston magazines rarely held any in storage. One source maintained that it was only once or twice in the whole war that even a day's supply was stored overnight (Crawford 1945).

It has been estimated that Holston produced a total of 434,000 tons of Composition B during World War II, which translates to almost one billion pounds (868 million) of the high-explosive (Crawford 1945; Holston Defense Corporation c. 1990:2). Not only was this production record one of the greatest industrial achievements of the war, but Holston officials saved the government considerable money in the process. In May of 1943, when the first lines began production, the manufacture of Composition B cost the government 30.5 cents a pound. By August 1945, the price had dropped to 10.5 cents per pound (Crawford 1945).

TECHNOLOGY

The Holston Process

The heart of Holston Ordnance Works was the manufacturing area (506 Area), which contained the 10 production lines. However, the support facilities essential to the continuous feed process were equally important. Up to this point, the manufacturing procedures employed at Holston have been touched on only briefly. This section explores these procedures in greater detail using information from a variety of published sources such as the Historic American Engineering Record TN-10 (1986); Holston Defense Corporation (1963, c. 1990, c. 1992); Siegel et al. (1982); TEC (1942g); and Wood (1989). Knowledgeable informants such as George Fletcher, Ernie Botts, Joe Davy, Dave Stauffer, Don Henley, William C. Hill, and Carson Wilson were also interviewed about the history of the facility. While none was old enough to have worked at Holston during the war, many remember the original process as told to them by previous workers.

Based on technology and chemistry perfected at the TEC pilot plants, the Holston process was based on two types of operations, both occurring simultaneously. One was the production line, where RDX and finally Composition B were manufactured in linear progression from C building to N building. The other consists of the feedstocks and the various loop processes that permitted the production lines to function as a continuous process.

Because everything revolved around service to the production line, this discussion will be oriented accordingly. The feedstocks and other support functions will be brought into the discussion where they occur in the process. The processes described here and in the alterations section are depicted graphically in Figure 9.

C Buildings, 503 Area, and Area A

As mentioned previously, the C buildings were the main staging area for RDX production (Figures 10 and 11). A number of chemicals were brought together at the C buildings, where the first mixings in the RDX process occurred. The materials brought to the C buildings (usually by rail) were either purchased from outside vendors or were manufactured and processed at Holston. The chemicals included:

hexamine (from outside vendor)
acetic acid (from outside vendor and recycled from Area A)
nitric acid (from 503 Area)
ammonium nitrate (from outside vender until summer 1944 and periodically after that)

During World War II, acetic anhydride, which also came from Area A, was brought directly to the D buildings, rather than the C buildings. Here, it will be discussed with the other C building chemicals since acetic acid and acetic anhydride were all part of the same process in Area A.

The initial process, beginning in the C buildings, is best understood by first tracing the chemicals to their place of origin. Hexamine, the combination of ammonia and formaldehyde, was always supplied by outside government vendors. Until the summer of 1944, this was also true of ammonium nitrate. Most of the other chemicals were produced at Holston.

The 503 Area (also known as the 300 Series Buildings) was originally designed to make nitric acid, based on a technology borrowed directly from DuPont and the Hercules Powder Company. This process entailed taking liquid ammonia, turning it into ammonia vapor, then mixing the vapor with a platinum catalyst and air, which had been heated and compressed. This produced nitrogen oxides, which were then oxidized with air and mixed with water to create a 60 percent solution of nitric acid (Kane 1995:154). Until the summer of 1944, ammonium nitrate was purchased from outside vendors and stockpiled in the C buildings or the 11 magazines west of the 503 Area. Before the summer of 1944, when the ammonium nitrate manufacturing plant (Building 330) went on line in the 503 Area, ammonium nitrate was mixed with nitric acid in the C buildings. Afterwards, this earlier practice was revived whenever there were problems with the ammonium nitrate plant (HOW 1945b:II). Due to the great changes that occurred in the 503 Area in 1944 and 1945, this area will be discussed in greater detail in the Alterations to the Process section of this report.

Acetic acid was also brought to the C buildings. Some was purchased from outside vendors, but much was reclaimed from the recycling process in Area A. The processing of acetic acid, together with the production of acetic anhydride, was the main function of Area A. The Area A process began with weak (60 percent) acetic acid. From this, strong or glacial (99 percent) acetic acid, and finally, acetic anhydride were produced. Much of the weak acetic acid that entered this process in Area A came from the B buildings, or Recovery Area, immediately west of the production lines. The Recovery Loop associated with the B buildings has not yet been discussed; it is more closely associated with the function of the E buildings and will be discussed in that connection.

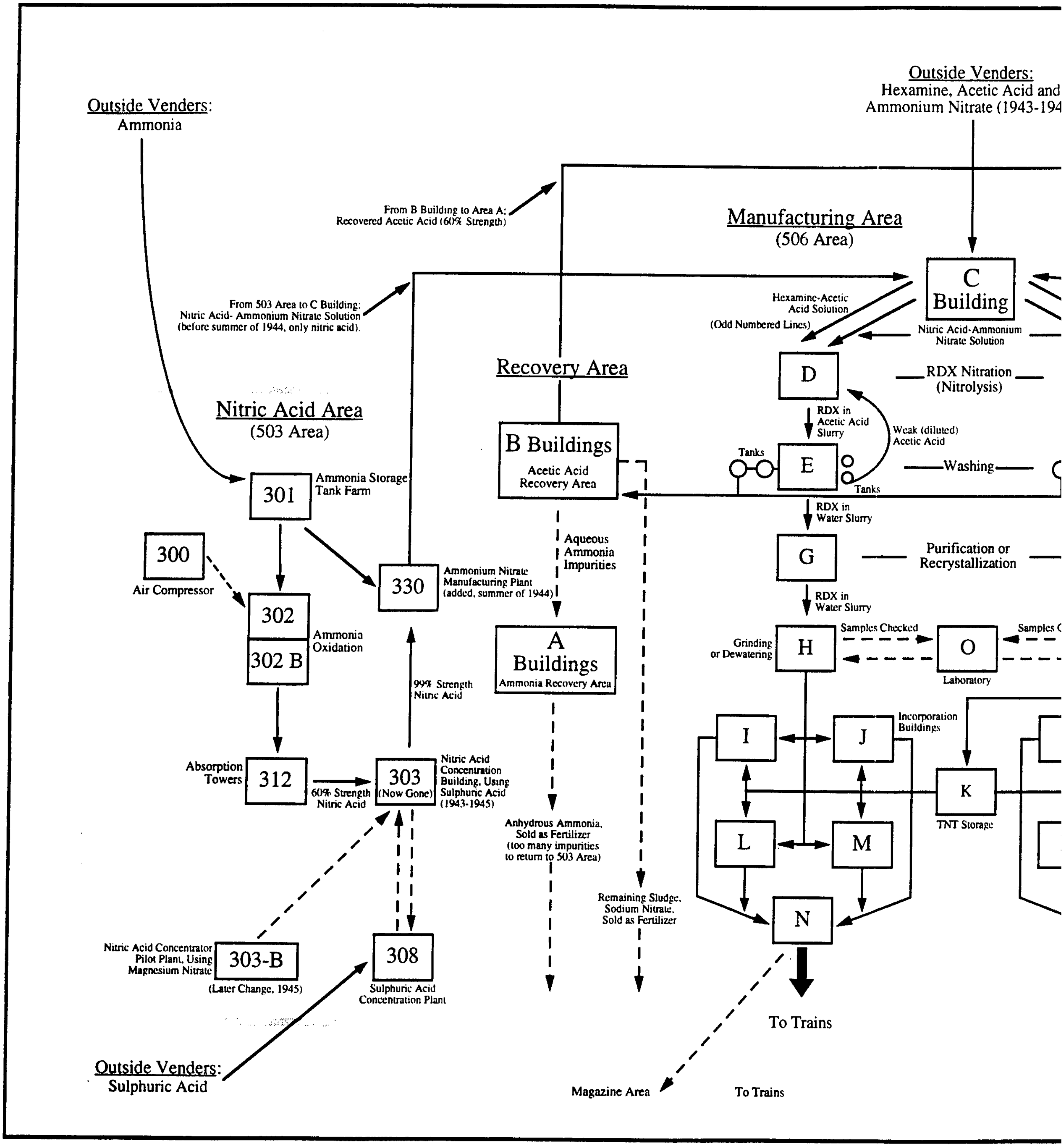
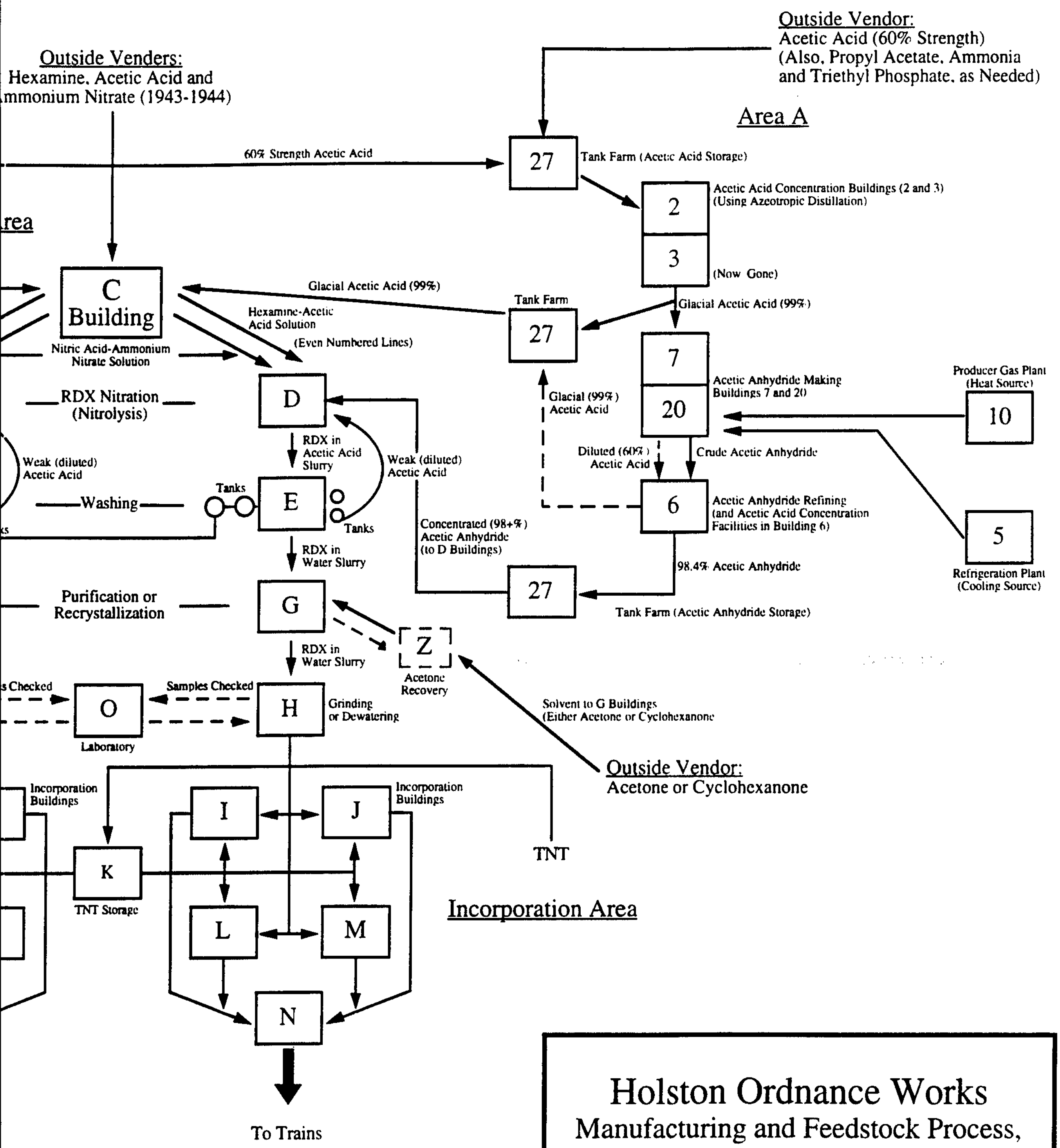


Figure 9. Holston Ordnance Works Manufacturing and Feedstock Processes as of Summer 1944.

(1)



Holston Ordnance Works
Manufacturing and Feedstock Process, as of Summer 1944

2

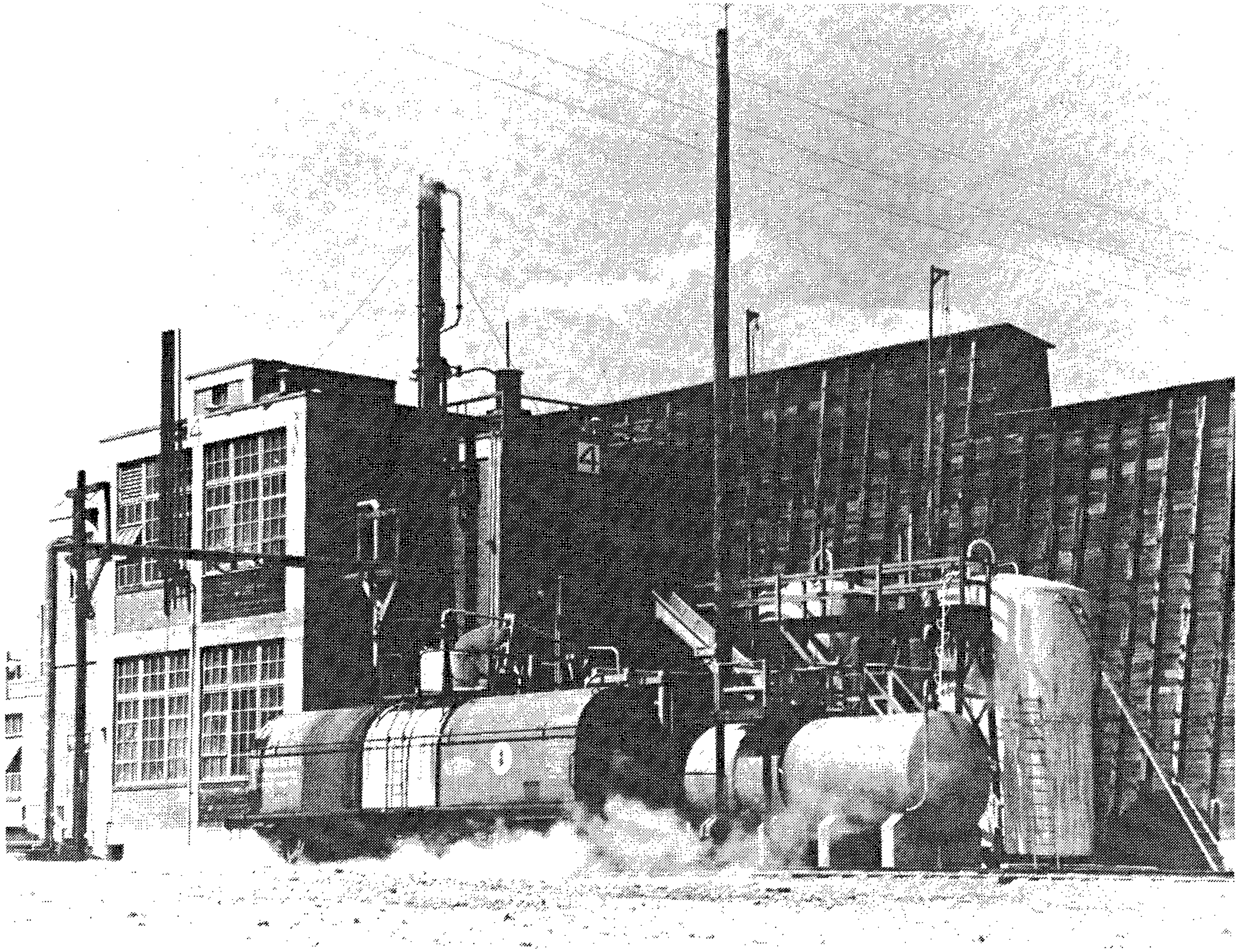


Figure 10. C Building (courtesy of Holston AAP Photo Set No. 19-B [on file Engineering Vault, Building 26]).

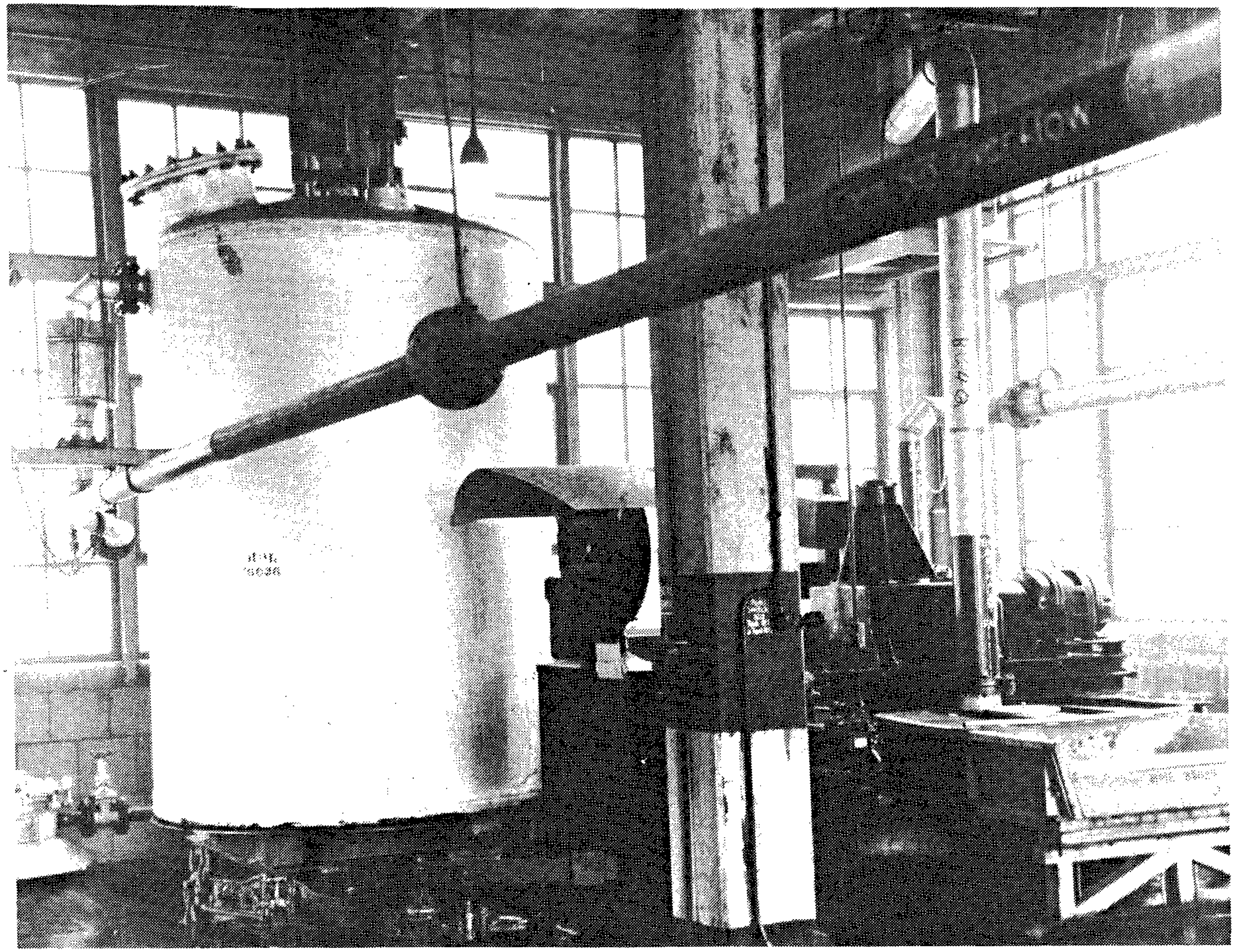


Figure 11. Interior Mixing Area, C Building (courtesy of Holston AAP Photo Set 19-B [on file Engineering Vault, Building 26]).

Weak acetic acid, either from an outside vendor or recycled from the B buildings, first entered Area A through the tank farm, also known as Building 27 (Figure 12). From this storage area, the acid was sent to Buildings 2 and 3 for acetic acid concentration (Building 3 was torn down in the 1970s). In Building 2, an eight-story structure, weak acetic acid was distilled using the azeotropic process (MacDonald and Mack 1984:34), complete with entraining fluid, crack furnaces, and scrubbers (Figures 13 and 14). The end result was glacial (99 percent) acetic acid, which was then piped back to the tank farm (Building 27). From there, 20 percent of the concentrated acid was shipped to the C buildings in Area B, while the remaining 80 percent went to Buildings 7 and 20 for conversion into acetic anhydride.

In Buildings 7 and 20, gas-fired cracking furnaces were used to heat the glacial acetic acid and "crack" it into water vapor and ketene gas (Figures 15, 16, and 17). The ketene was then "scrubbed" with fresh glacial acetic acid to form crude acetic anhydride and diluted acetic acid. In effect, acetic anhydride was produced by dehydrating glacial acetic acid (MacDonald and Mack 1984:33-36).

From Buildings 7 and 20, the crude acetic anhydride was piped to Building 6 for refining, after which the acetic anhydride was 98.4 percent pure (Figures 18 and 19). It was then returned to the tank farm for eventual shipment to the D buildings in the production area.

Back at the C buildings, bags of hexamine were shipped in by rail from outside vendors. Strong acetic acid from vendors or from Area A was stored in outside tanks. The hexamine and acetic acid were mixed in dissolver tanks inside the C buildings. Nitric acid was shipped over from the 503 Area to the C buildings where it was mixed with ammonium nitrate to prepare the nitric acid-ammonium nitrate solution that would be piped to the D buildings.

D Buildings

From C, the chemical solutions were shipped to the five-story D buildings (Figures 20 and 21). The final mixing took place there that resulted in crude RDX. Specifically, the hexamine and acetic acid solution was mixed with the nitric acid and ammonium nitrate solution; acetic anhydride was added to keep water out of the process. This combination led to the nitration or reaction process that actually created RDX. Mixed in large tanks, the solutions generated a great amount of heat as the nitration process took place. Elaborate "reactor legs," supported on stilts, cooled the mixture in long runs outside the building. As the reaction cooled, the mixture, now a crude form of RDX, was piped to age tanks and finally simmer tanks, after which it was ready for the E buildings.

E Building and Recovery Area (B Buildings)

Crude RDX was piped to the E building in the form of a spent acetic acid slurry. In the E building, the RDX was washed, replacing the acetic acid with water (Figures 22 and 23). This operation began on the second floor, where the RDX in acid slurry entered the wash tanks. Using the batch method, each tank load was then processed. First, a vacuum was used to pull most of the acetic acid away from the RDX through a false bottom in the tanks. This acid, now diluted and tainted with RDX, was then piped into large storage tanks on the west side of the building. The RDX remaining in the wash tank, a 21 inch-thick cake, was then rinsed with water for a final cleaning. The acetic acid from this process, even more diluted than the material from the vacuum cleaning, was piped to smaller tanks on the east side of the building. The first batch of acid, stored in the larger tanks was then piped to the B buildings just west of the production lines. The diluted acid resulting from the final wash was returned to simmer tanks in D building.

The acetic acid separated by vacuum pull from the crude RDX went from the E building area to one of the B buildings located west of the production lines in the Recovery Area (Figure 24). There, the B buildings

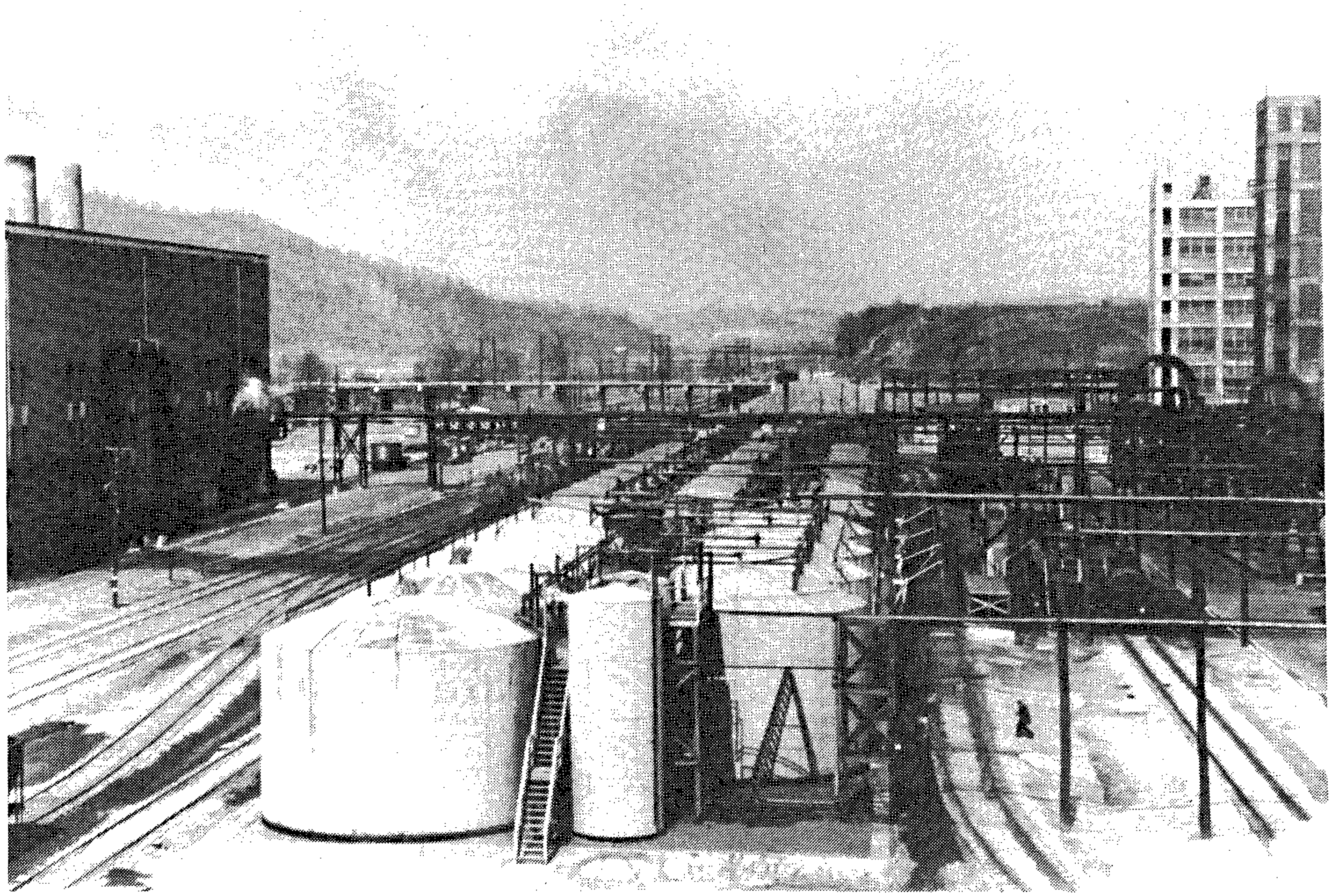


Figure 12. Tank Farm, Building 27, Area A (courtesy of Holston AAP Photo Set No. 5 [on file Engineering Vault, Building 26]).

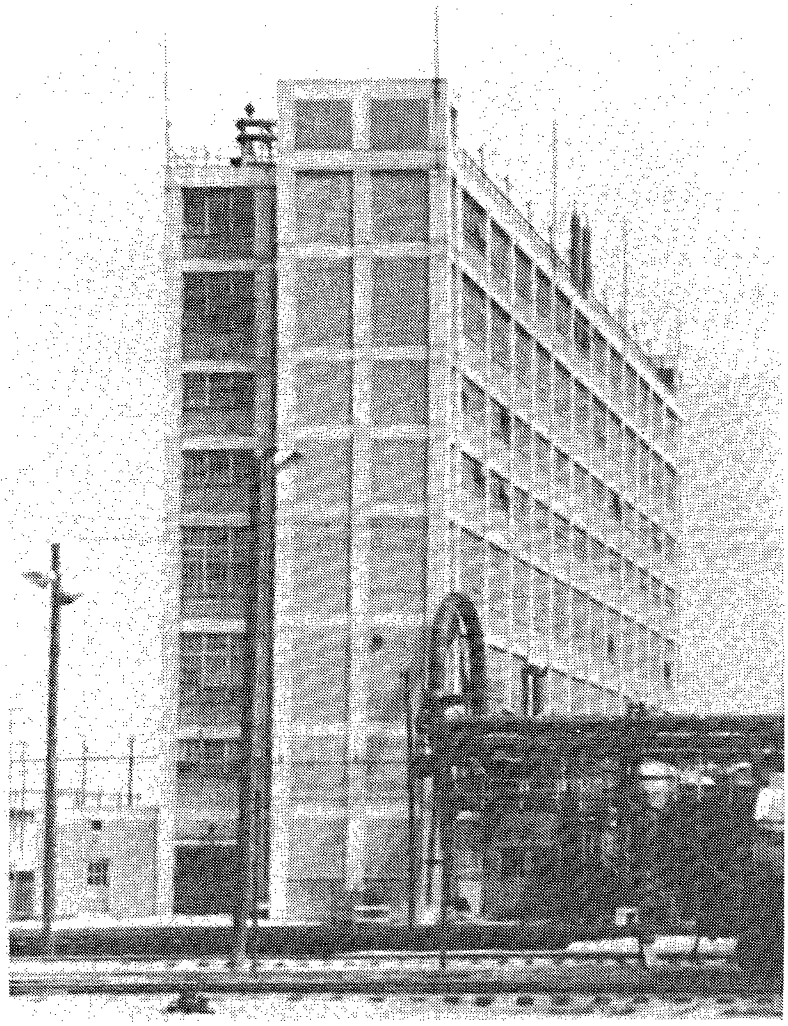


Figure 13. Acetic Acid Concentration, Building 2, Area A (courtesy of Holston AAP Photo Set No. 2 [on file Engineering Vault, Building 26]).

separated the acetic acid from the residual RDX left in the acid. The recovered RDX was shipped back to the E building. The recovered acetic acid, now at 60 percent strength, was shipped back to Area A for conversion into glacial acetic acid and acetic anhydride. This recovery operation was based on the process worked out by TEC in its very first government contract, signed in November 1941. Now, at last, the various loops that fed into the C, D, and E buildings were connected. After RDX leaves the E building, the process follows a more direct chain from building to building.

G Building

RDX was piped from E building to G building in a water slurry. It was then pumped into four dissolver tanks on the top floor (Figure 25). The batch in each tank was heated to 92° Fahrenheit, then solvent was added for a three-hour simmer (in the first months of operation, the solvent was acetone; later, it was cyclohexanone). After simmering, each batch was dropped into tanks on the next floor, where new RDX crystals were allowed to form. The whole purpose of the operation in G building was to purify and

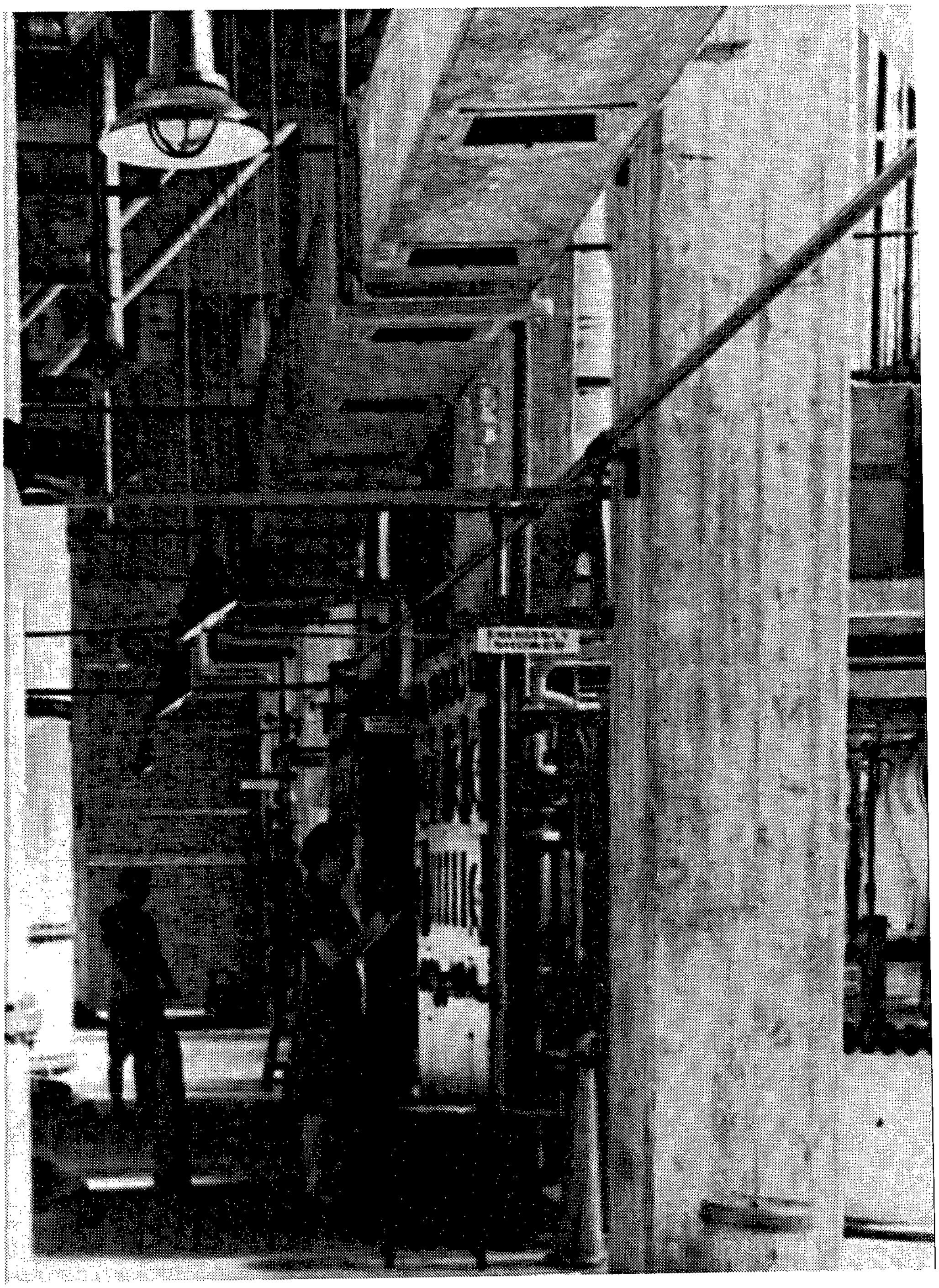


Figure 14. Interior, Building 2, Area A (courtesy of Holston AAP Photo Set No. 2 [on file Engineering Vault, Building 26]).

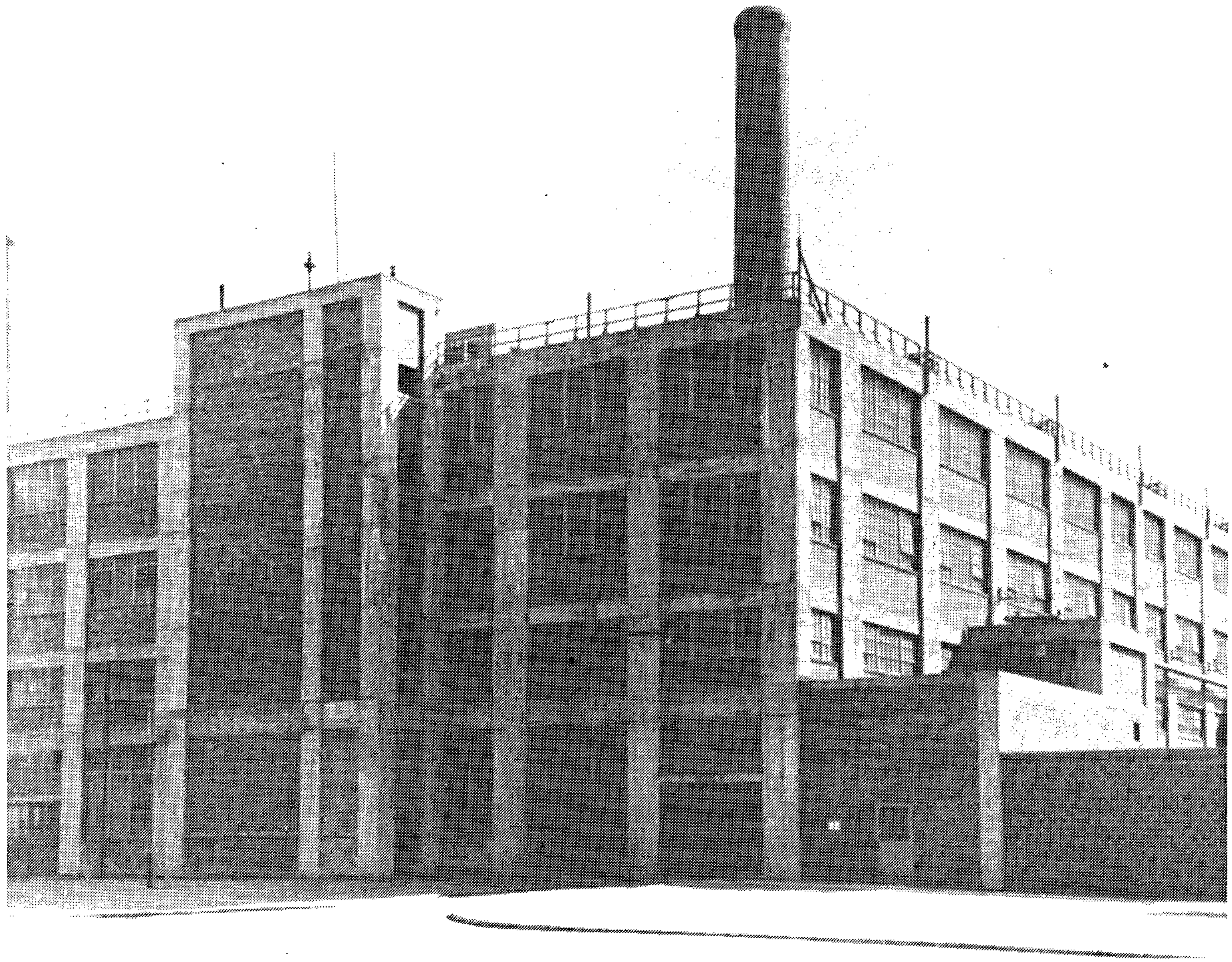


Figure 15. Anhydride Making, Building 7, Area A (courtesy of Holston AAP Photo Set No. 7 [on file Engineering Vault, Building 26]).

Figure 16. Interior, Building 7, Area A (courtesy of Holston AAP Photo Set No. 7 [on file Engineering Vault, Building 26]).

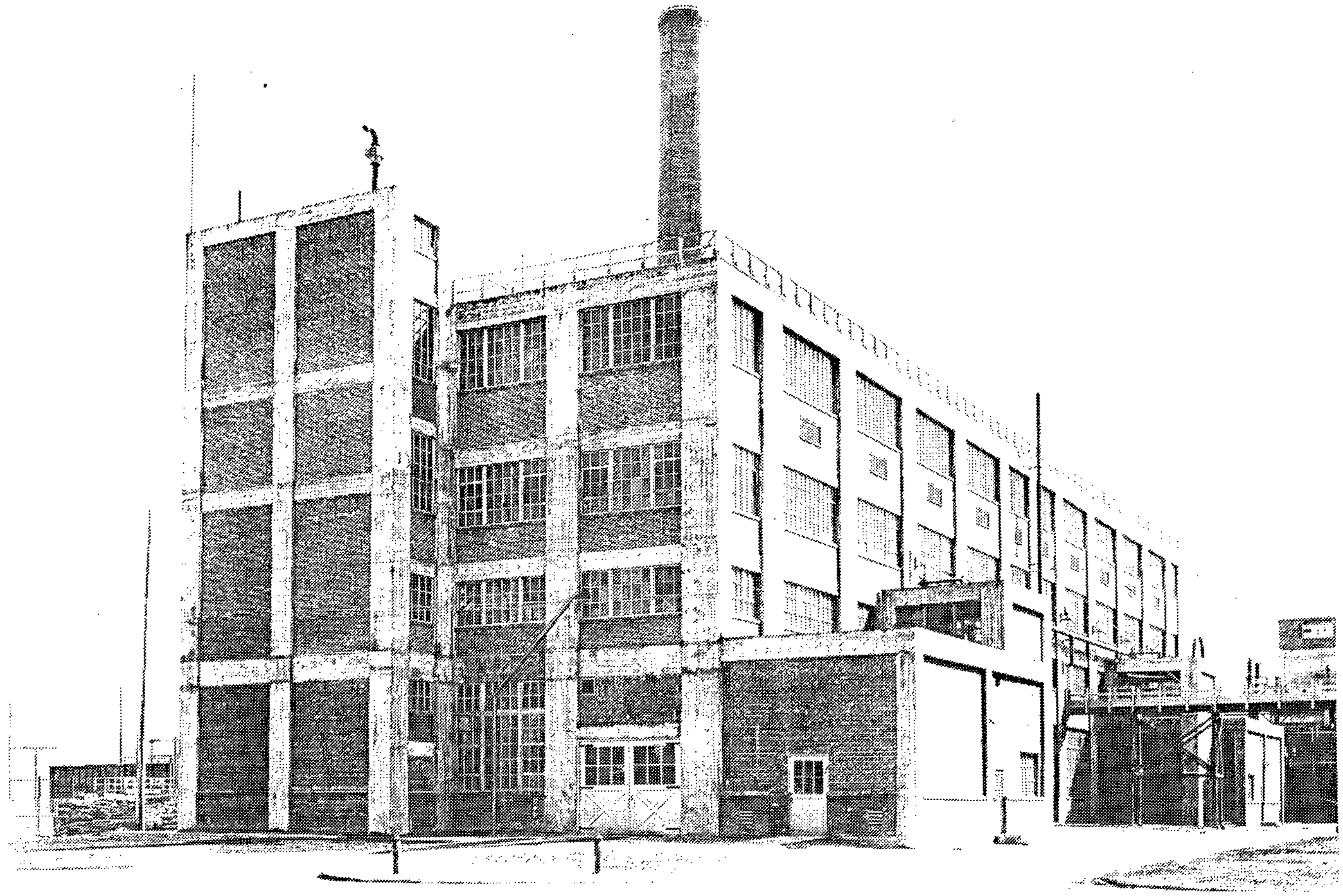


Figure 17. Anhydride Making, Building 20, Area A (courtesy of Holston AAP Photo Set No. 13 [on file Engineering Vault, Building 26]).

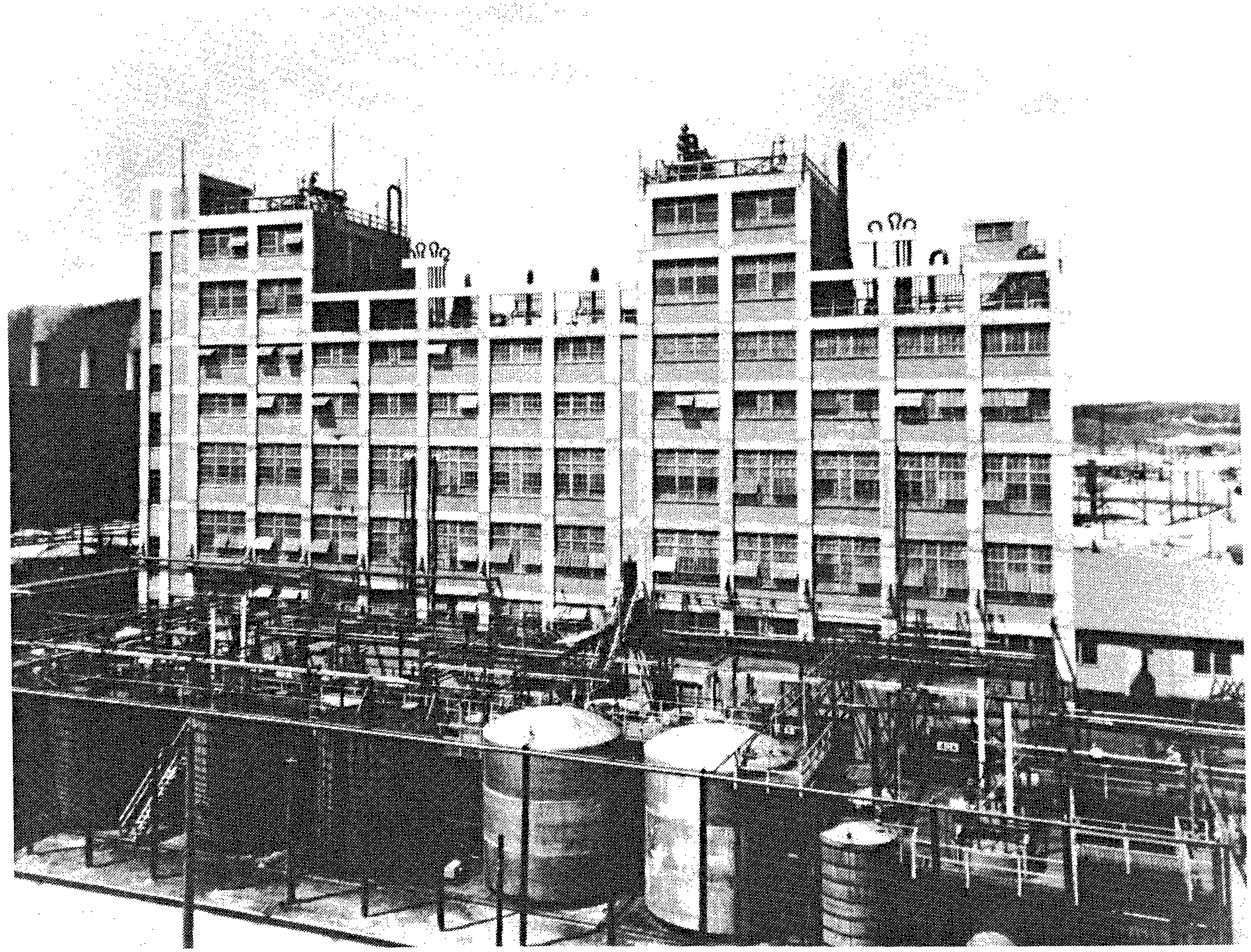


Figure 18. Anhydride Refining, Building 6, Area A (courtesy of Holston AAP Photo Set No. 6 [on file Engineering Vault, Building 26]).

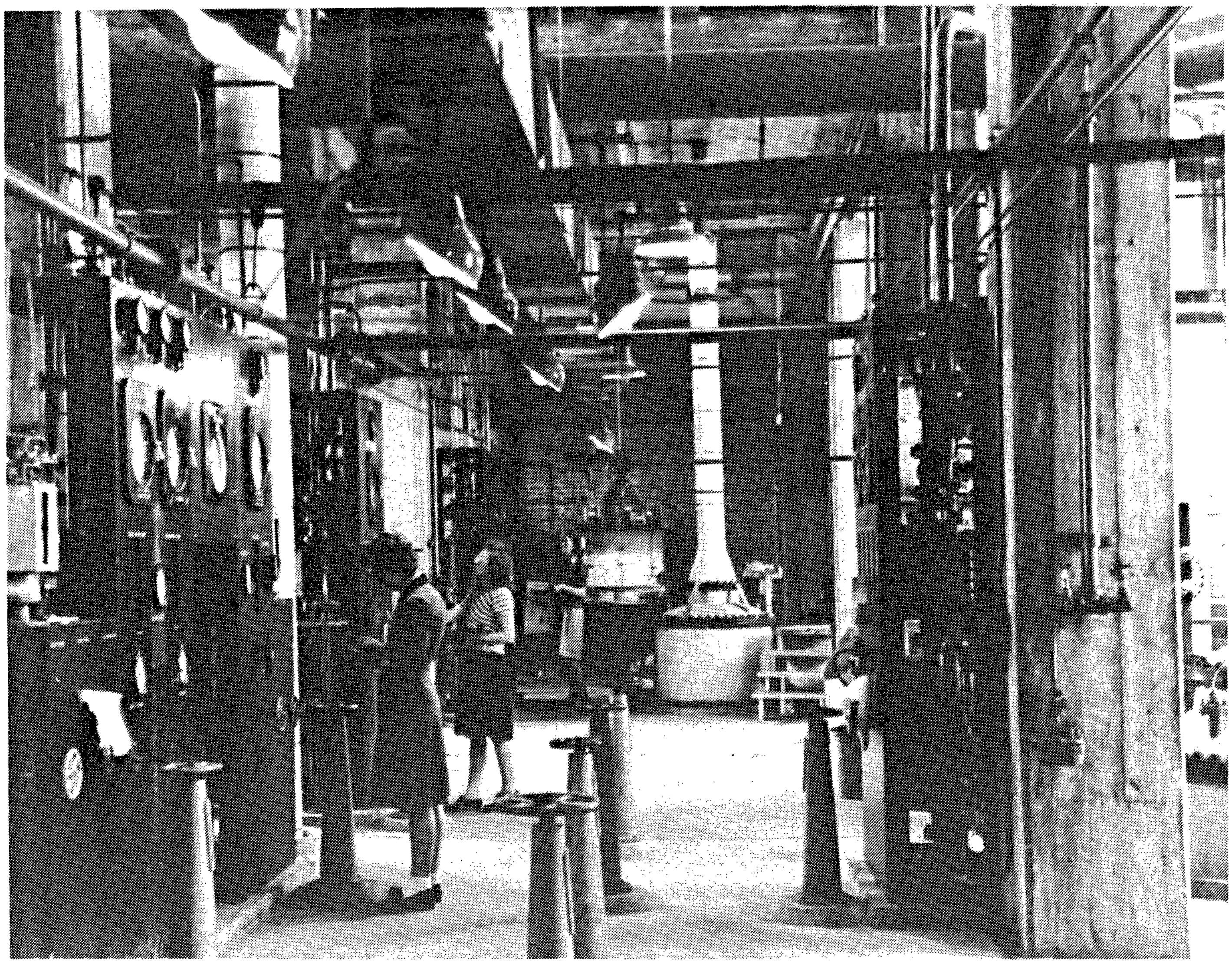


Figure 19. Interior, Building 6 (courtesy of Holston AAP Photo Set No. 6 [on file Engineering Vault, Building 26]).

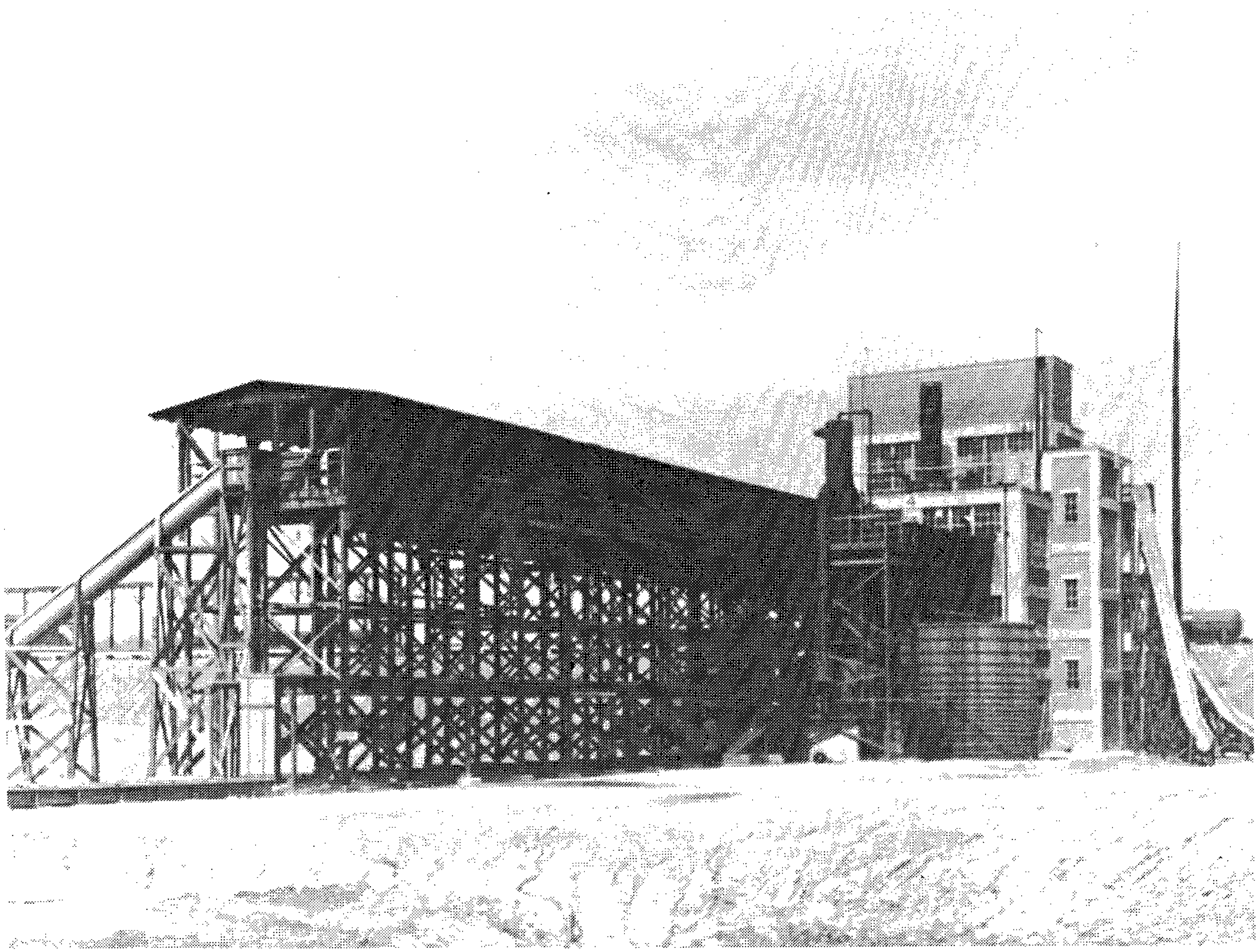


Figure 20. D Building with Reactor Leg, Area B (courtesy of Holston AAP Photo Set No. 20-B [on file Engineering Vault, Building 26]).

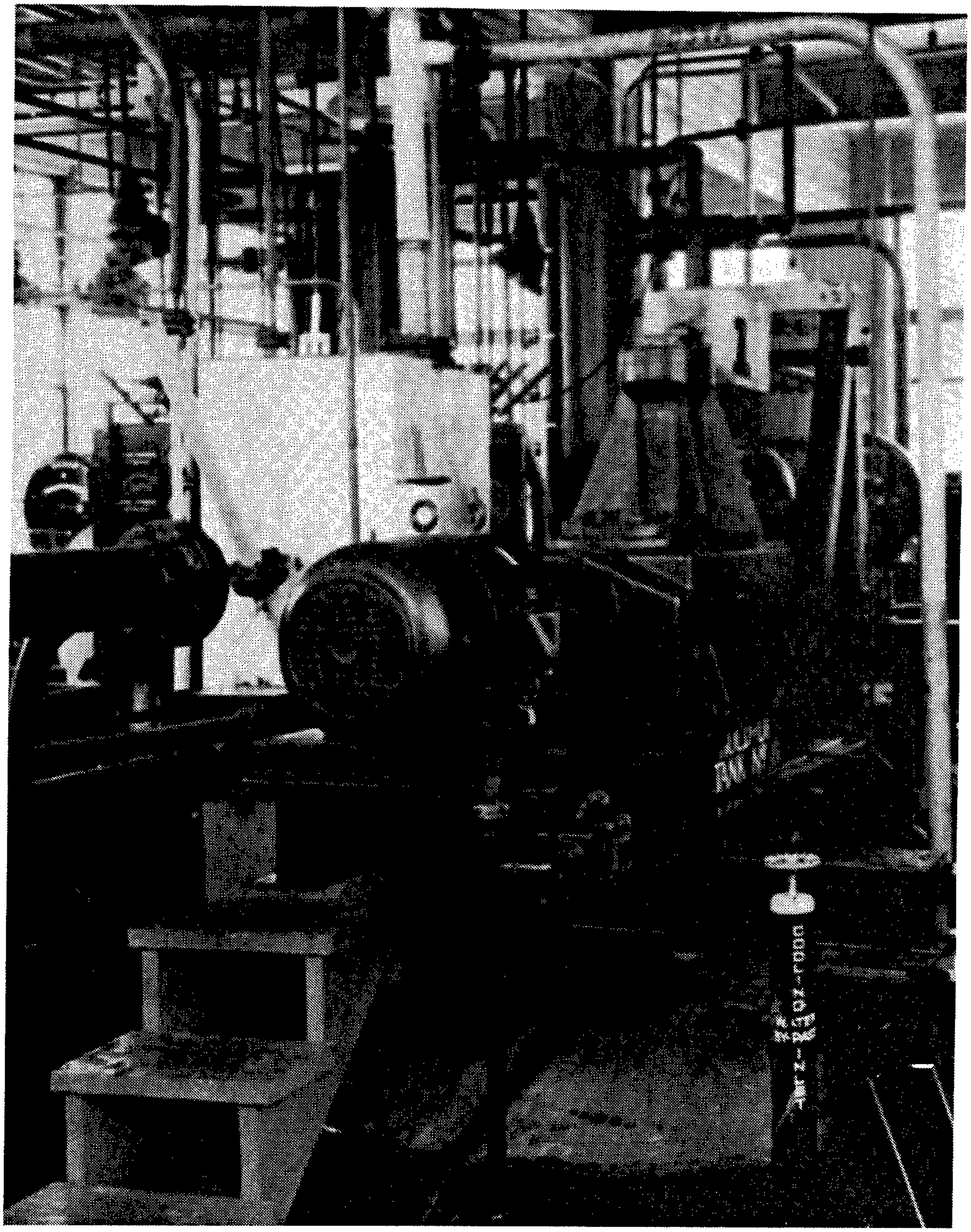


Figure 21. Interior, D Building (courtesy of Holston AAP Photo Set No. 20-B [on file Engineering Vault, Building 26]).

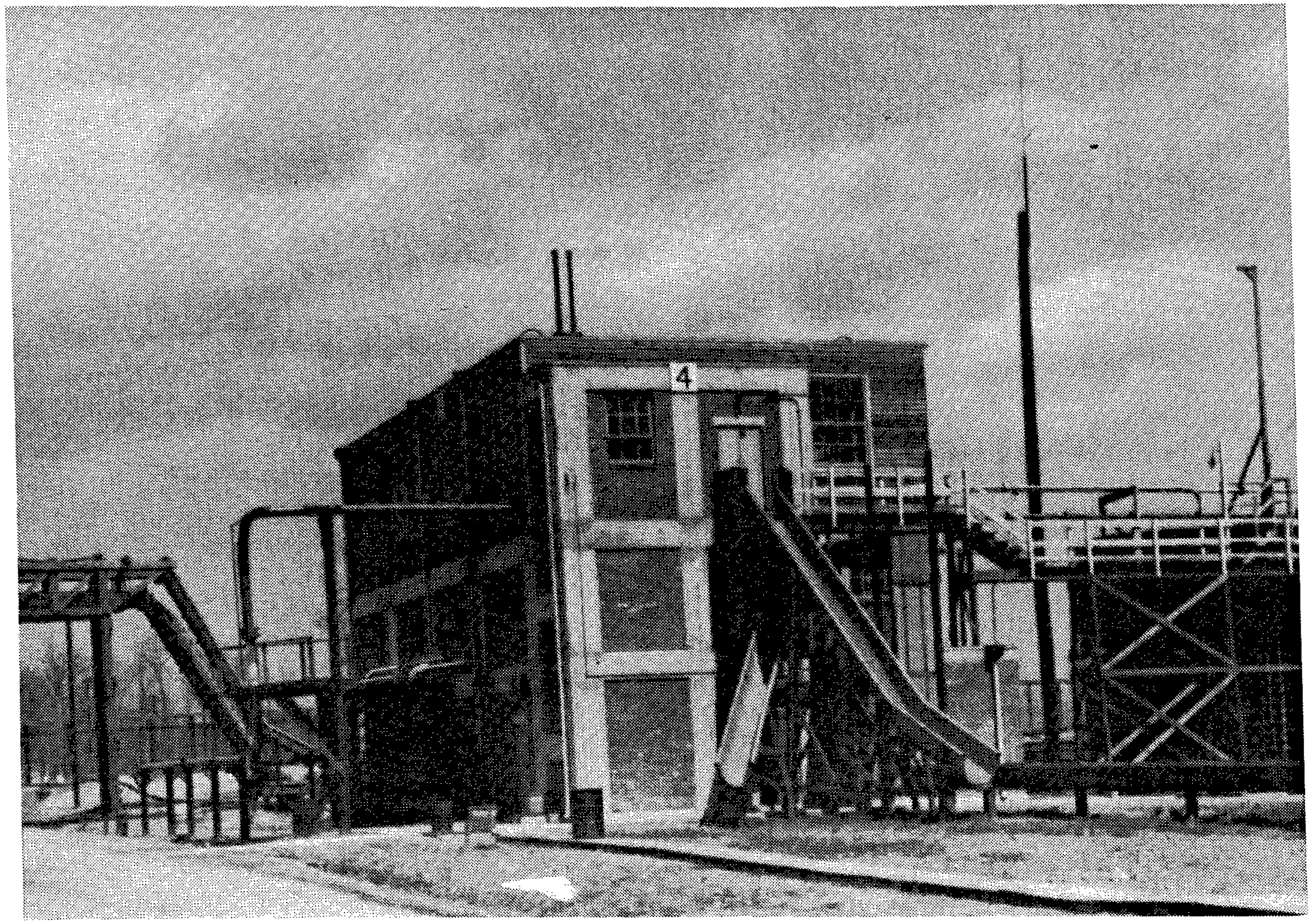


Figure 22. Washing, E Building, Area B (courtesy of Holston AAP Photo Set No. 21-B [on file Engineering Vault, Building 26]).

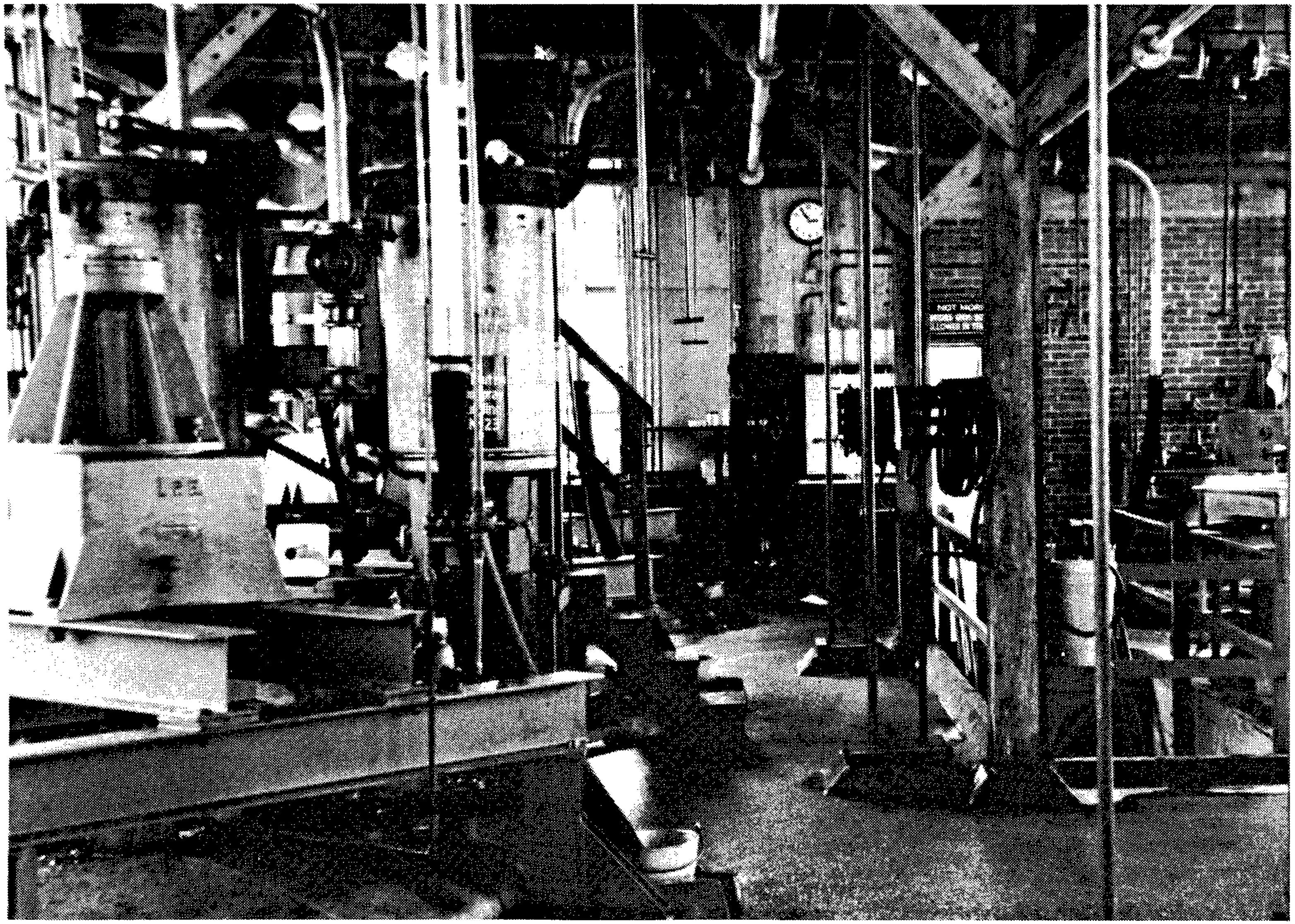


Figure 23. Interior, E Building (courtesy of Holston AAP Photo Set No. 21-B [on file Engineering Vault, Building 26]).

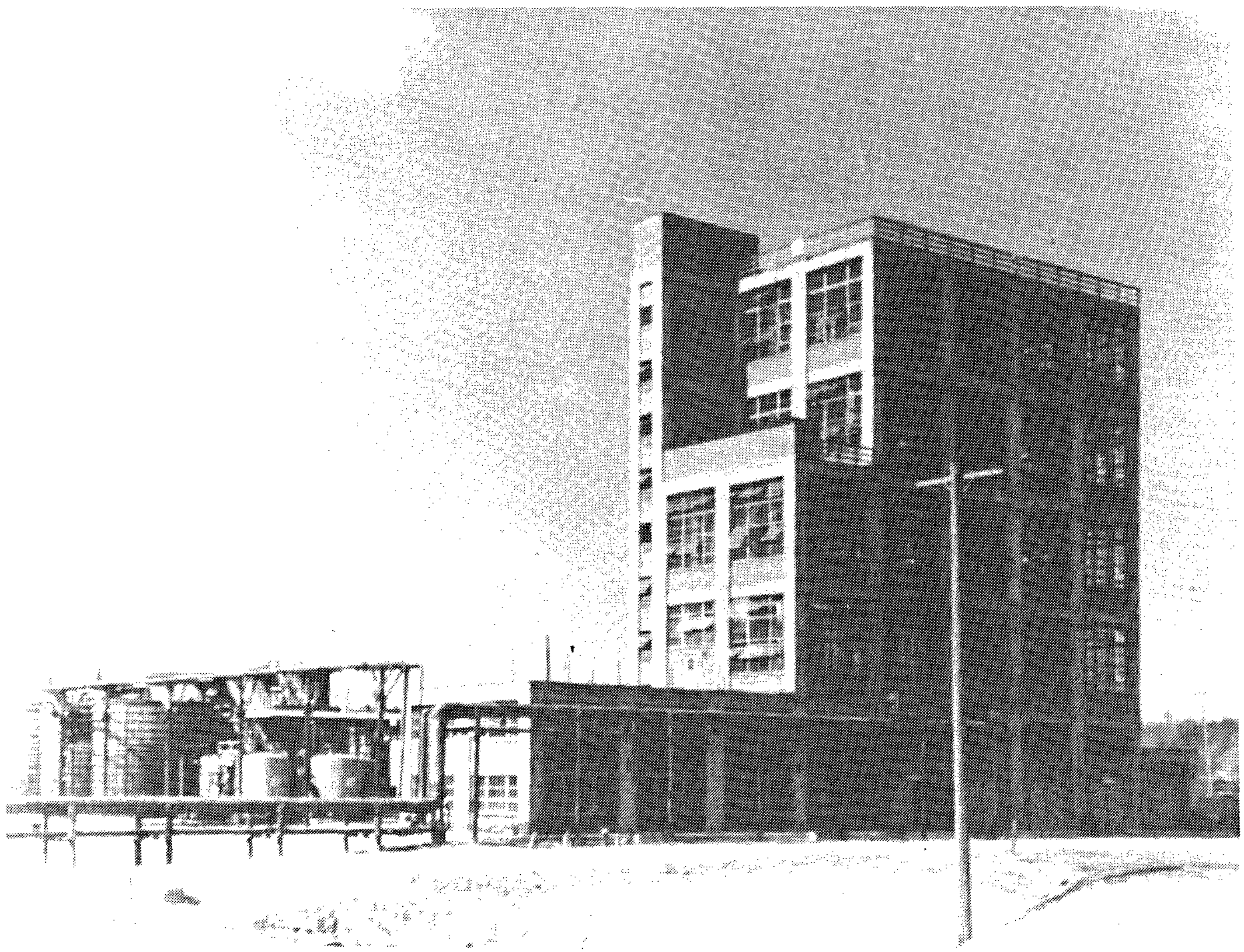


Figure 24. Recovery Area, Building B-11, Area B (courtesy of Holston AAP Photo Set No. 18-B [on file Engineering Vault, Building 26]).

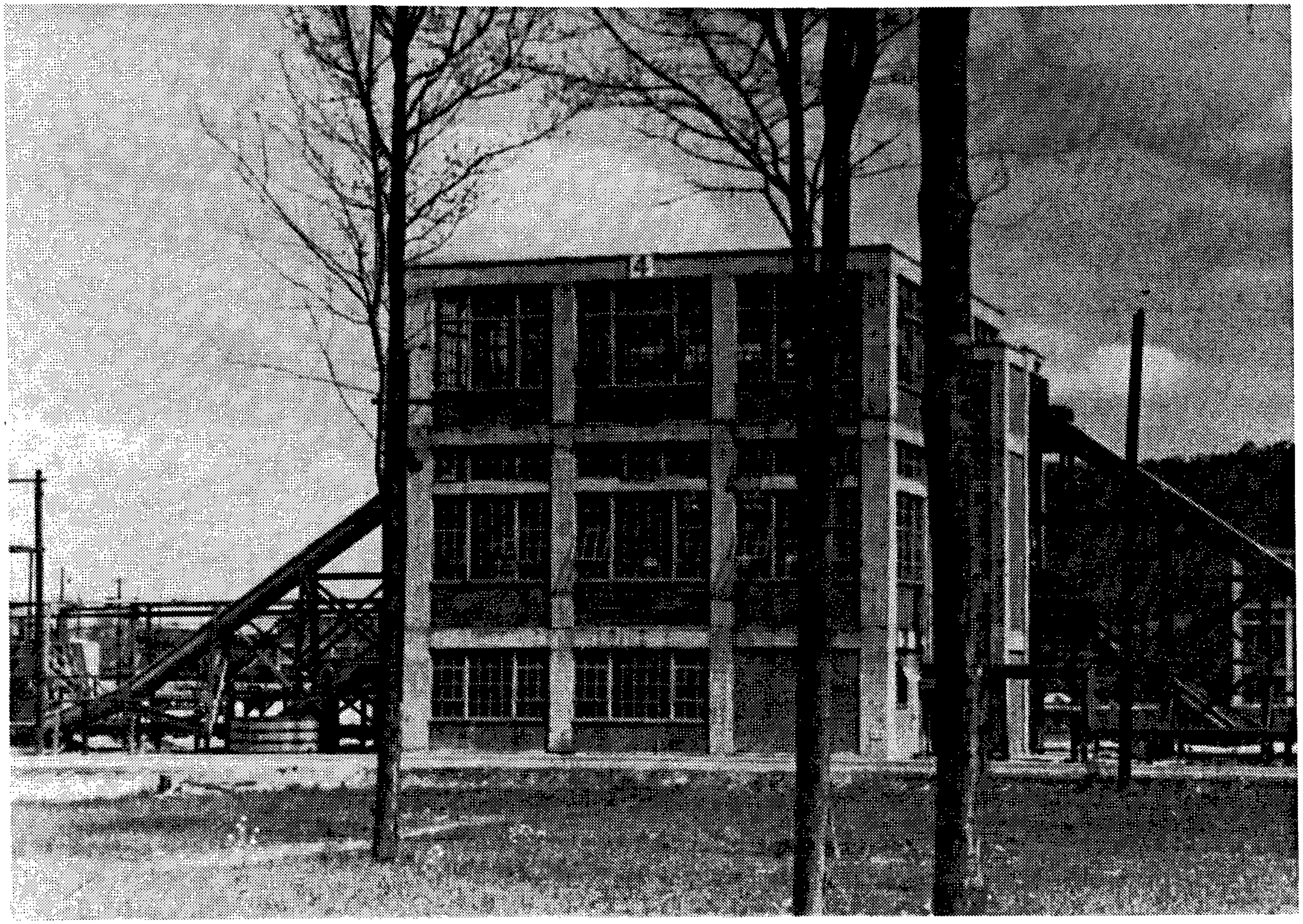


Figure 25. Purification, G Building, Area B (courtesy of Holston AAP Photo Set No. 23-B [on file Engineering Vault, Building 26]).

recrystallize RDX. This process entailed removing acetic acid from the existing crystals and creating new crystals untainted by the acid. No new water was added to the process, but the purified RDX still left the building in a water slurry.

H through N Buildings

At the next stop, H building, the final de-watering took place (Figures 26 and 27). It was here that the RDX was placed into "nutsches," or special boxes from which the water was extracted. Now in solid form, a sampling of RDX crystals was examined in O building (Figures 28 and 29), the analytical laboratory situated between each pair of H buildings.

If the RDX passed inspection, it was manually transported, by way of covered walkways, to one of the incorporation buildings (Figures 30, 31, and 32). There were four such buildings for each line (I, J, L, and M), and each was separated from the other by high wood frame barricades filled with earth. During World War II, each of these four buildings was identical and served the same purpose—to incorporate RDX with TNT in order to make Composition B. The TNT came from the K buildings, located between every two production lines (Figure 33).

At the four incorporation buildings, the TNT was melted in large kettles and stirred with a rotating agitator. The RDX was then added to the brew according to the necessary 60:40 proportion, which was then extruded through a special colander-like machine to mold the Composition B into a shape resembling "Hershey Kisses" (Figure 34). From the incorporation buildings, Composition B was packed in wooden boxes in the N buildings for immediate shipment (Figures 35 and 36). During this period, the Composition B magazines on the south side of the Holston River were rarely used. When Composition B left the N buildings for the trains, it was the terminus of one of the more remarkable industrial and chemical production processes developed during the war (Figure 37).

Alterations to the Process

Most of the inventions and innovations used on the Holston production line had been developed at the TEC pilot plants, before Holston was constructed. There were, however, a number of alterations made to the physical plant and to the process before the war ended in August of 1945.

Relatively mundane but of great importance was the addition of special pipelines and covered boxways to protect the process pipelines during winter. These additions were not part of the original plan, but were found necessary to keep acid and water slurries from freezing in the pipes between buildings (Fletcher, personal communication 1995).

Even though the basic Holston process had been established before Holston began construction, the process itself underwent experimentation throughout the war. One of the first experiments was a switch from Composition B to Composition B-2, which basically entailed the omission of the 1 percent wax in the TNT-RDX mix. This was done in August 1943, just a few months after Holston went on line, but production switched back to the original formula in early September, after the Army Air Corps expressed dissatisfaction with the results (HOW 1943a:X:2, 1943d:IX:1).

Experimentation continued in 1944 and 1945. Chemical solutions were tested frequently to find improved ways to create RDX (Burton and McNeeley 1944; Progress Report on Processes and Equipment 1945). It was discovered, for example, that cyclohexanone was a better solvent than acetone for the RDX recrystallization process and was thus used on a regular basis by the end of the war (L.G. Davy 1945). Research also continued on the continuous process, both for RDX and for Composition B. This was

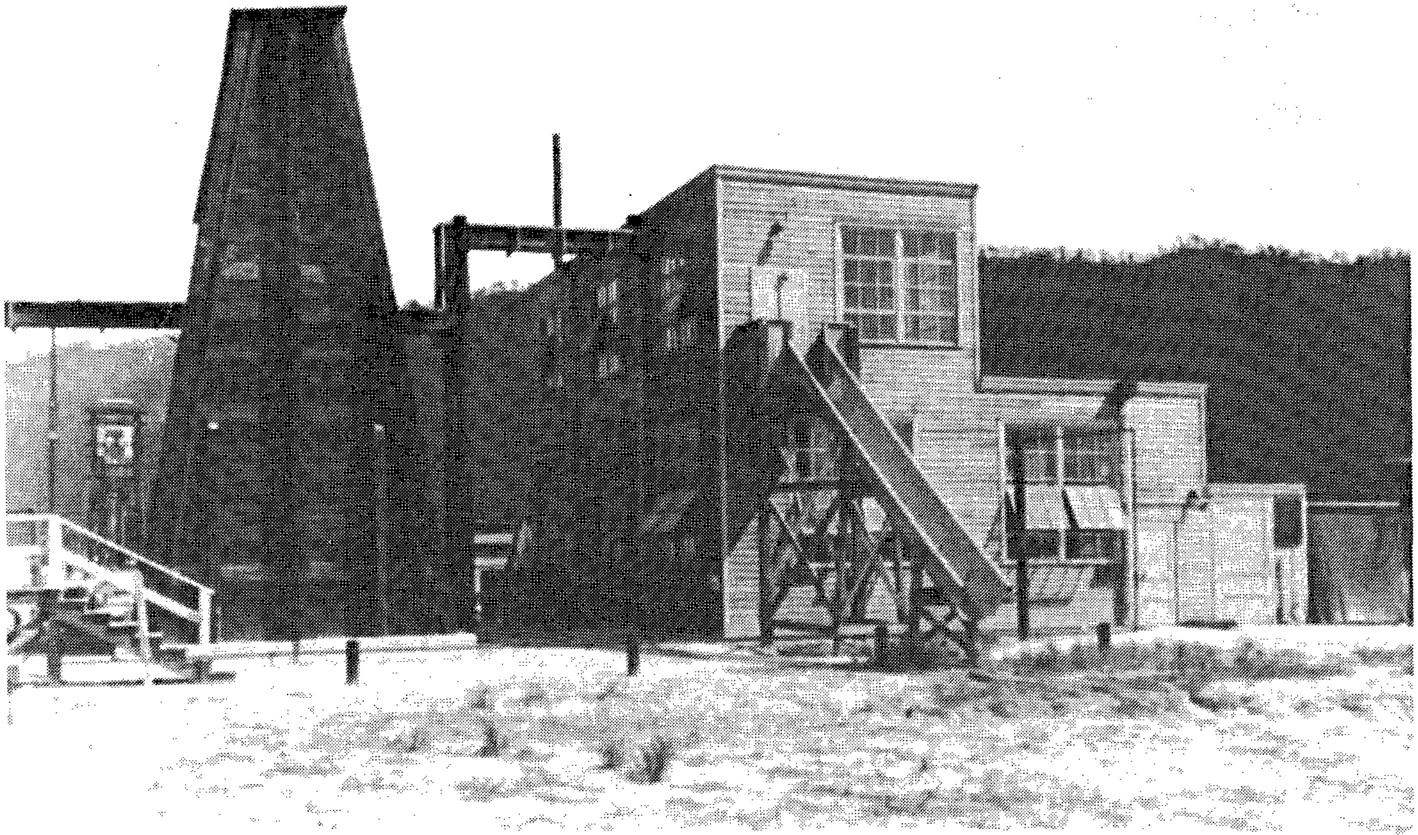


Figure 26. H Building, Area B (courtesy of Holston AAP Photo Set No. 24-B [on file Engineering Vault, Building 26]).

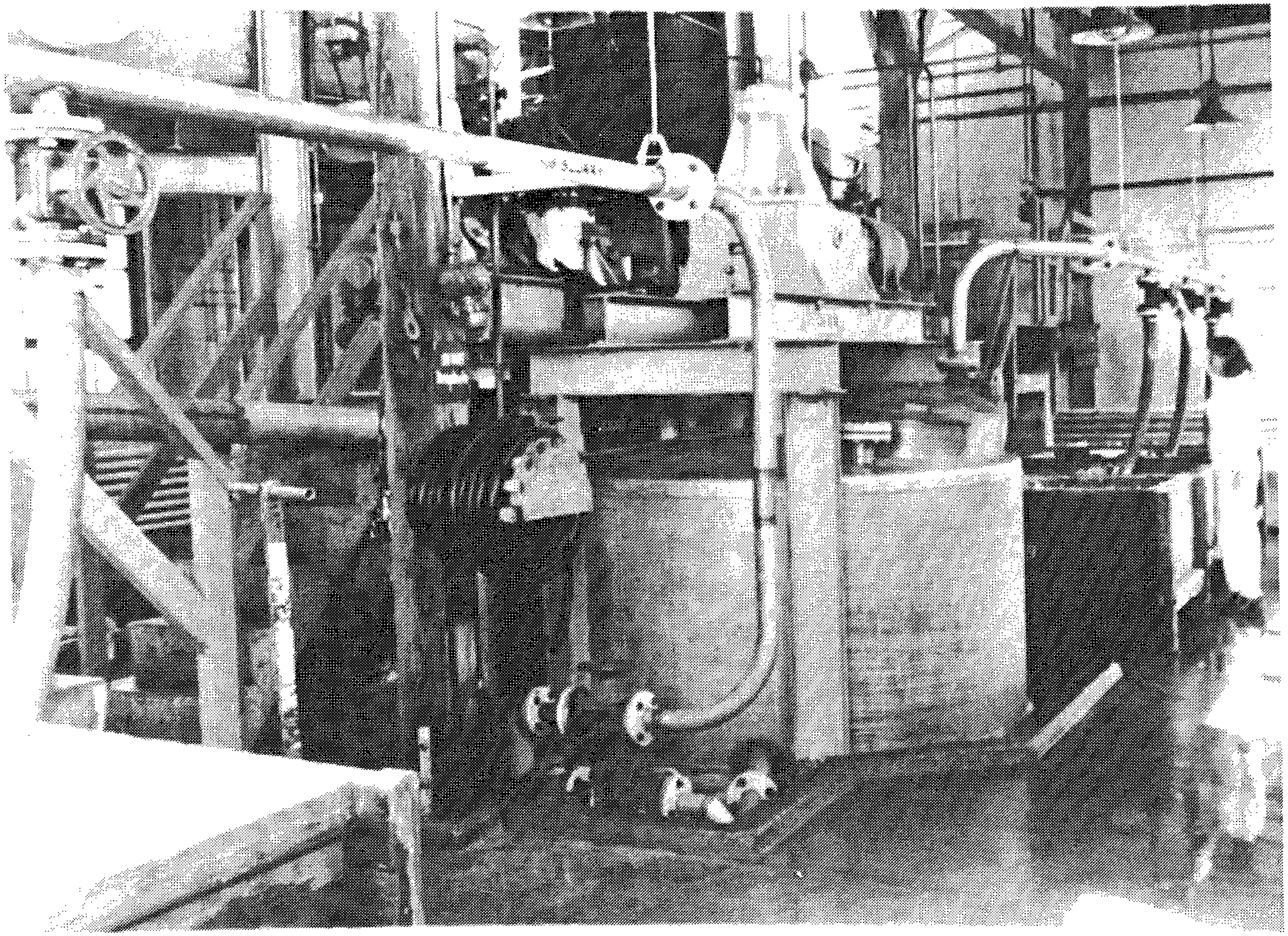


Figure 27. Interior, H Building (courtesy of Holston AAP Photo Set No. 24-B [on file Engineering Vault, Building 26]).

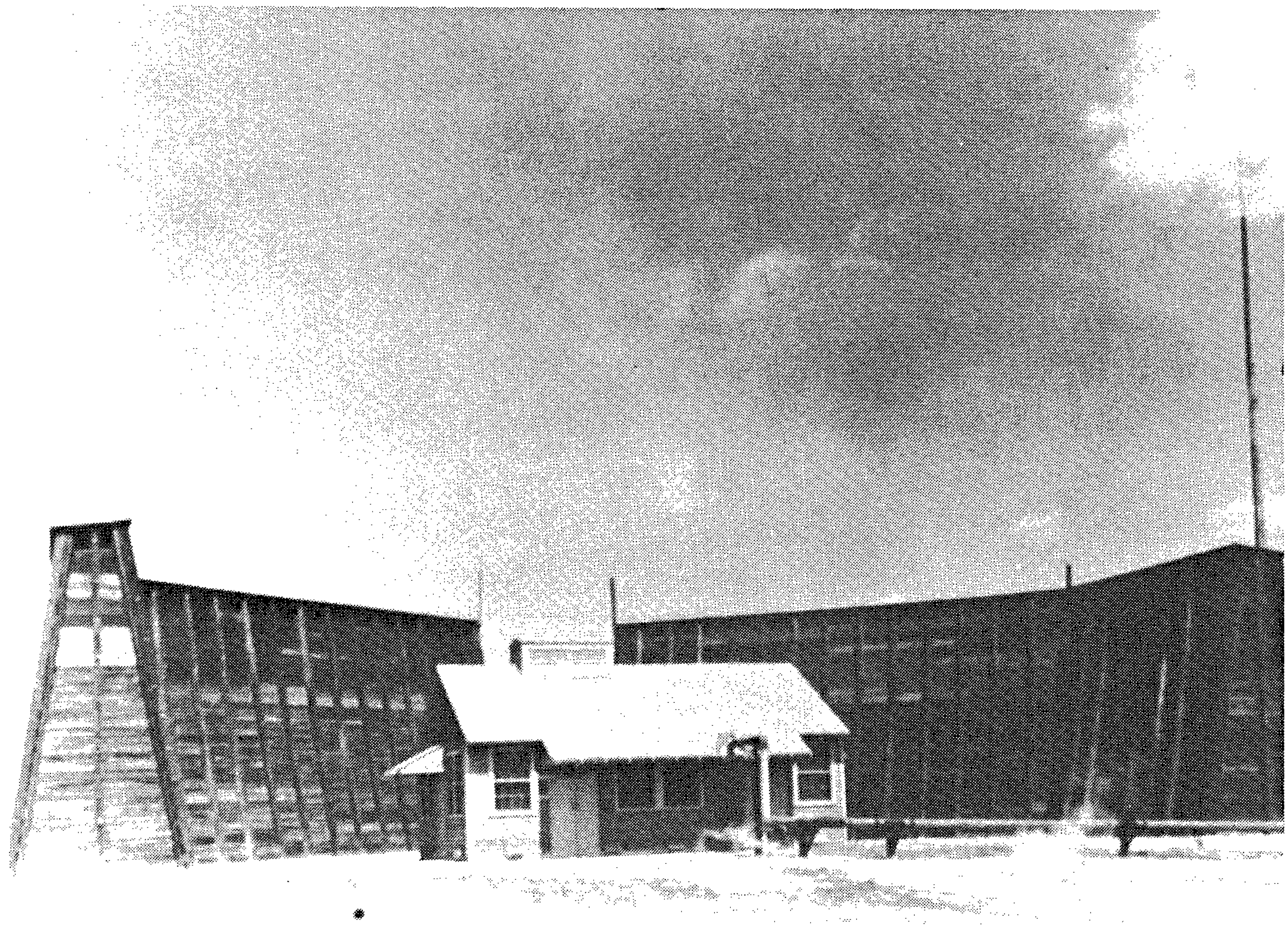


Figure 28. O Building, banked by barricades, Area B (courtesy of Holston AAP Photo Set No. 27-B [on file Engineering Vault, Building 26]).

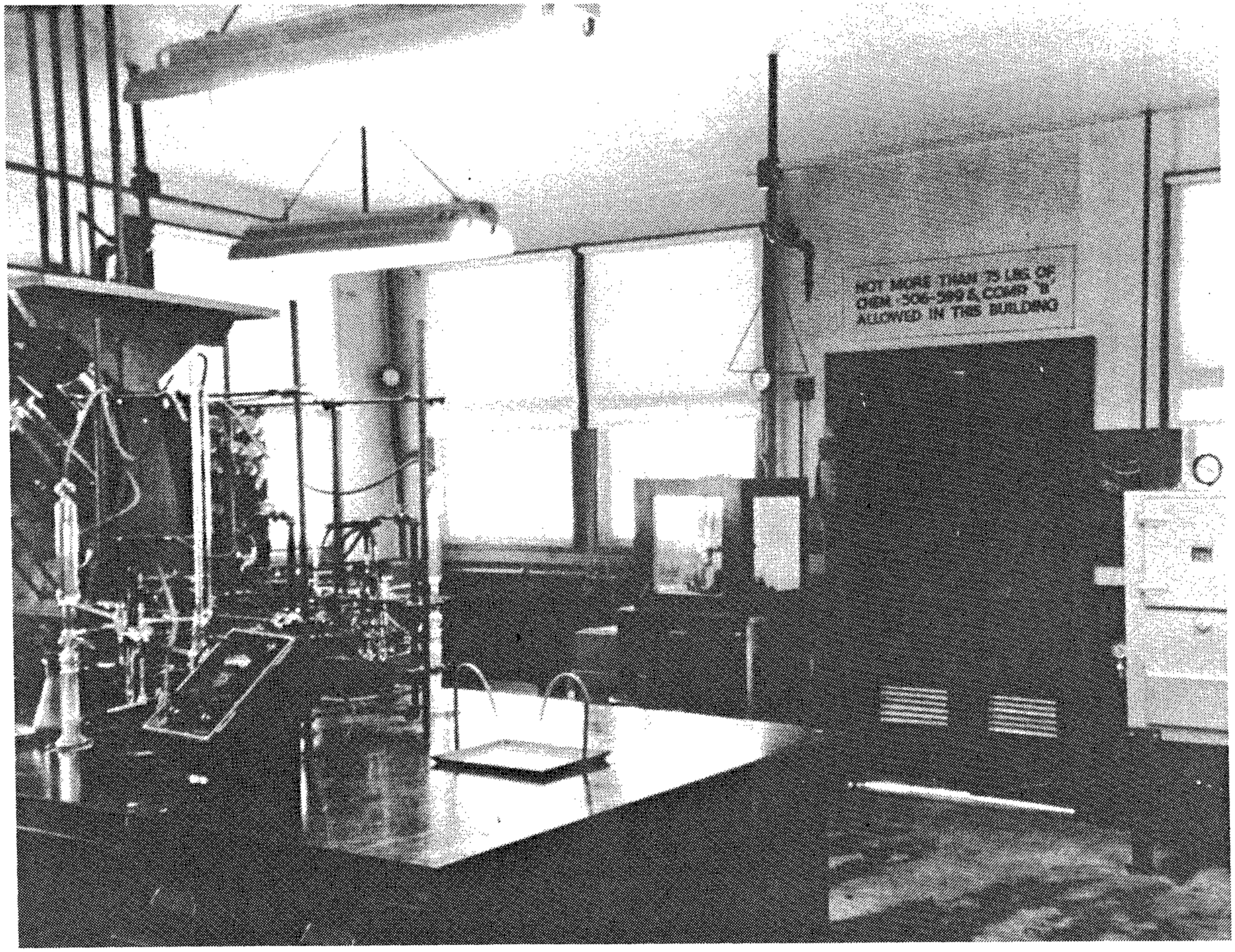


Figure 29. Interior, O Building (courtesy of Holston AAP Photo Set No. 27-B [on file Engineering Vault, Building 26]).

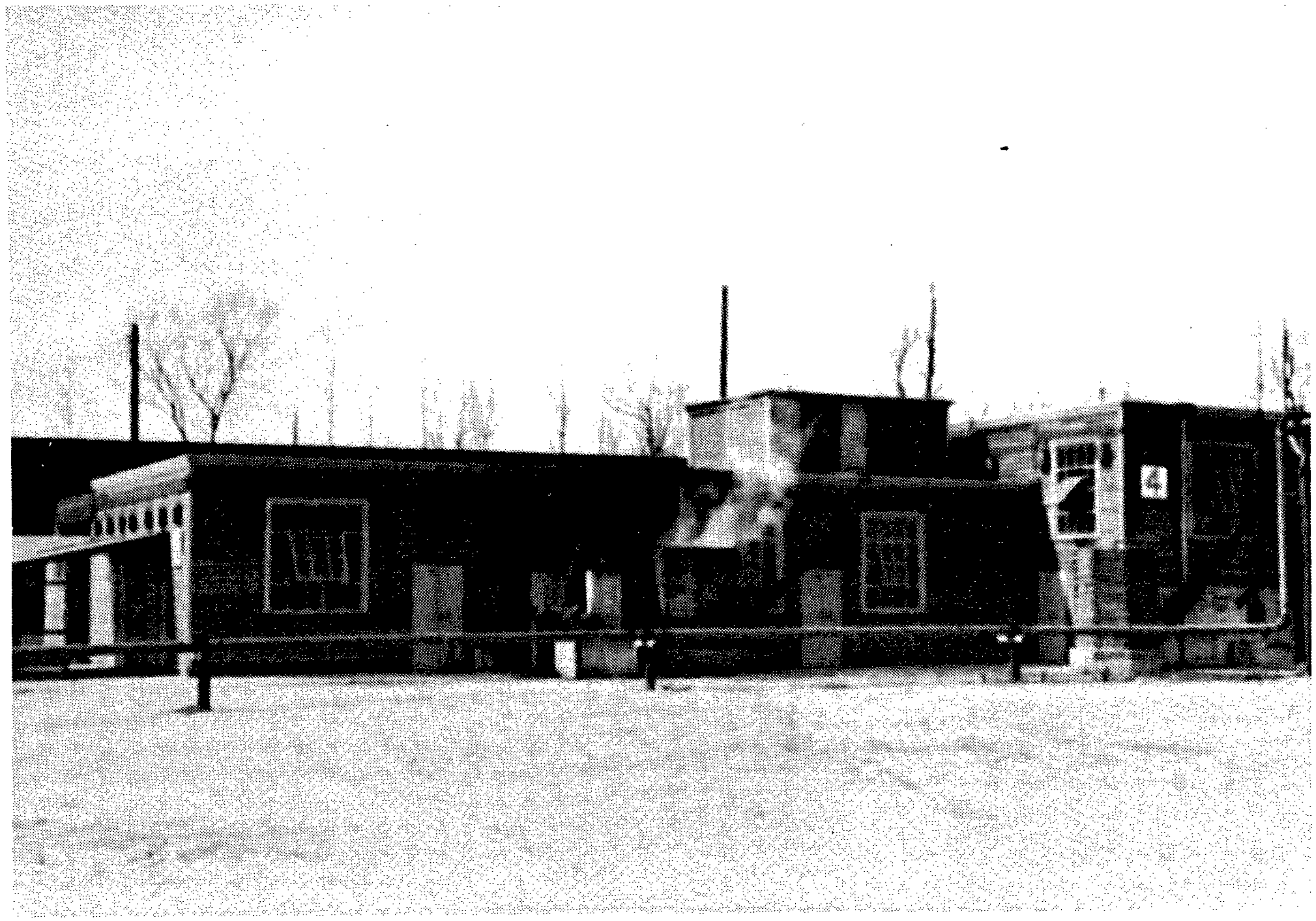


Figure 30. I, J, L, and M Buildings, Incorporation, Area B (courtesy of Holston AAP Photo Set No. 25-B [on file Engineering Vault, Building 26]).

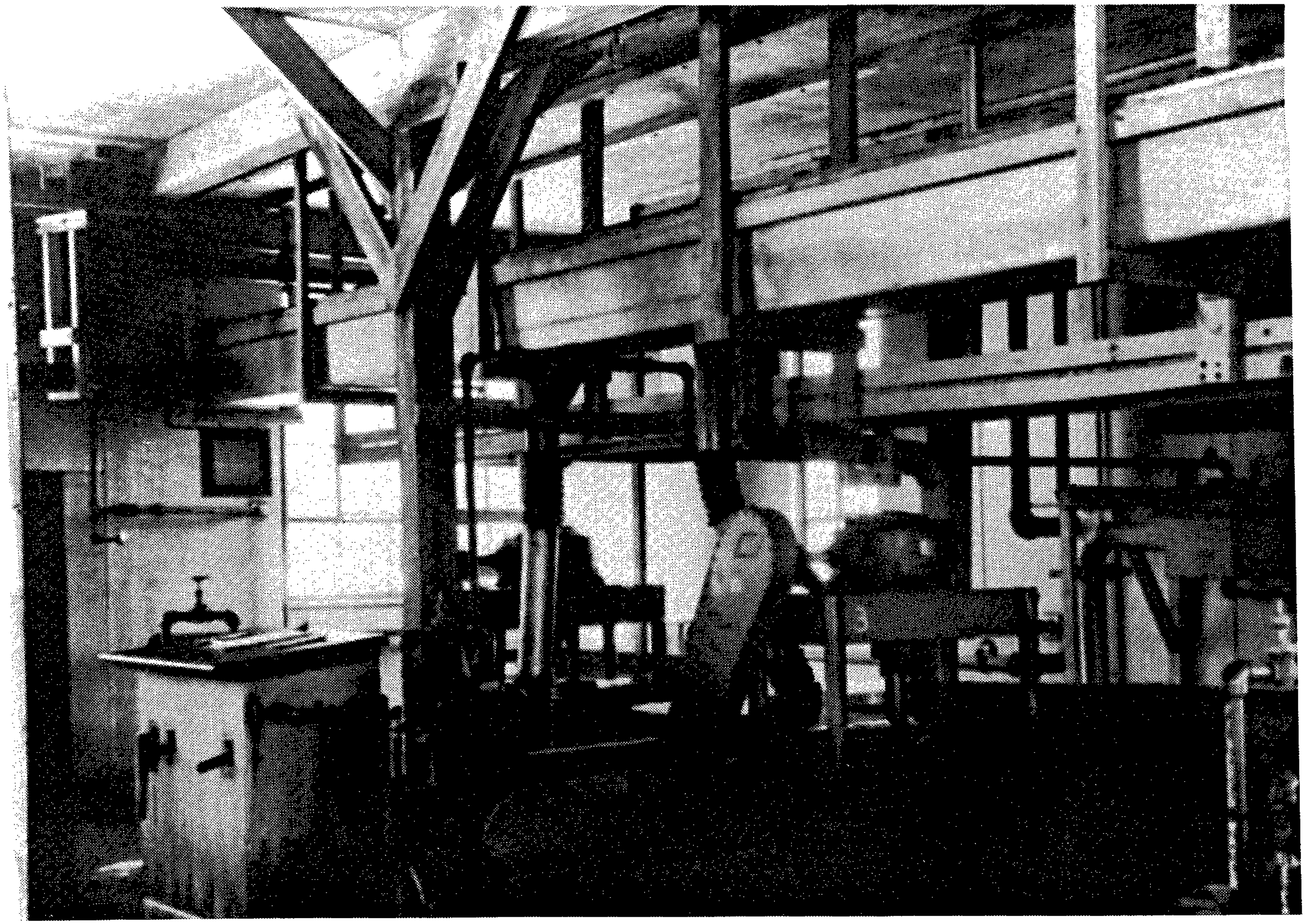


Figure 31. Interior, I, J, L, and M Buildings, with Incorporation Kettles (courtesy of Holston AAP Photo Set No. 25-B [on file Engineering Vault, Building 26]).

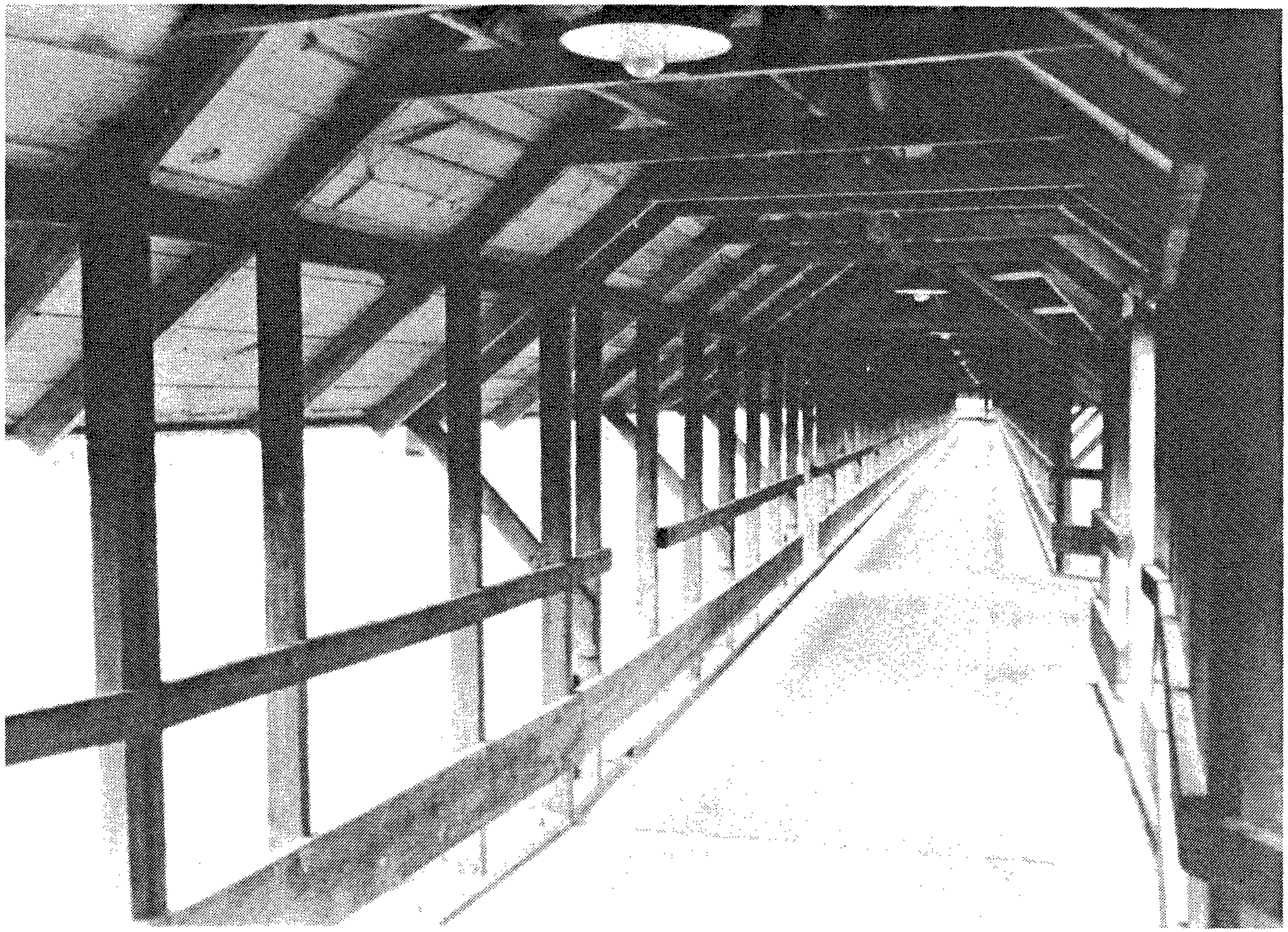


Figure 32. Covered walkways between Incorporation Buildings (courtesy of Holston AAP Photo Set No. 25-B [on file Engineering Vault, Building 26]).

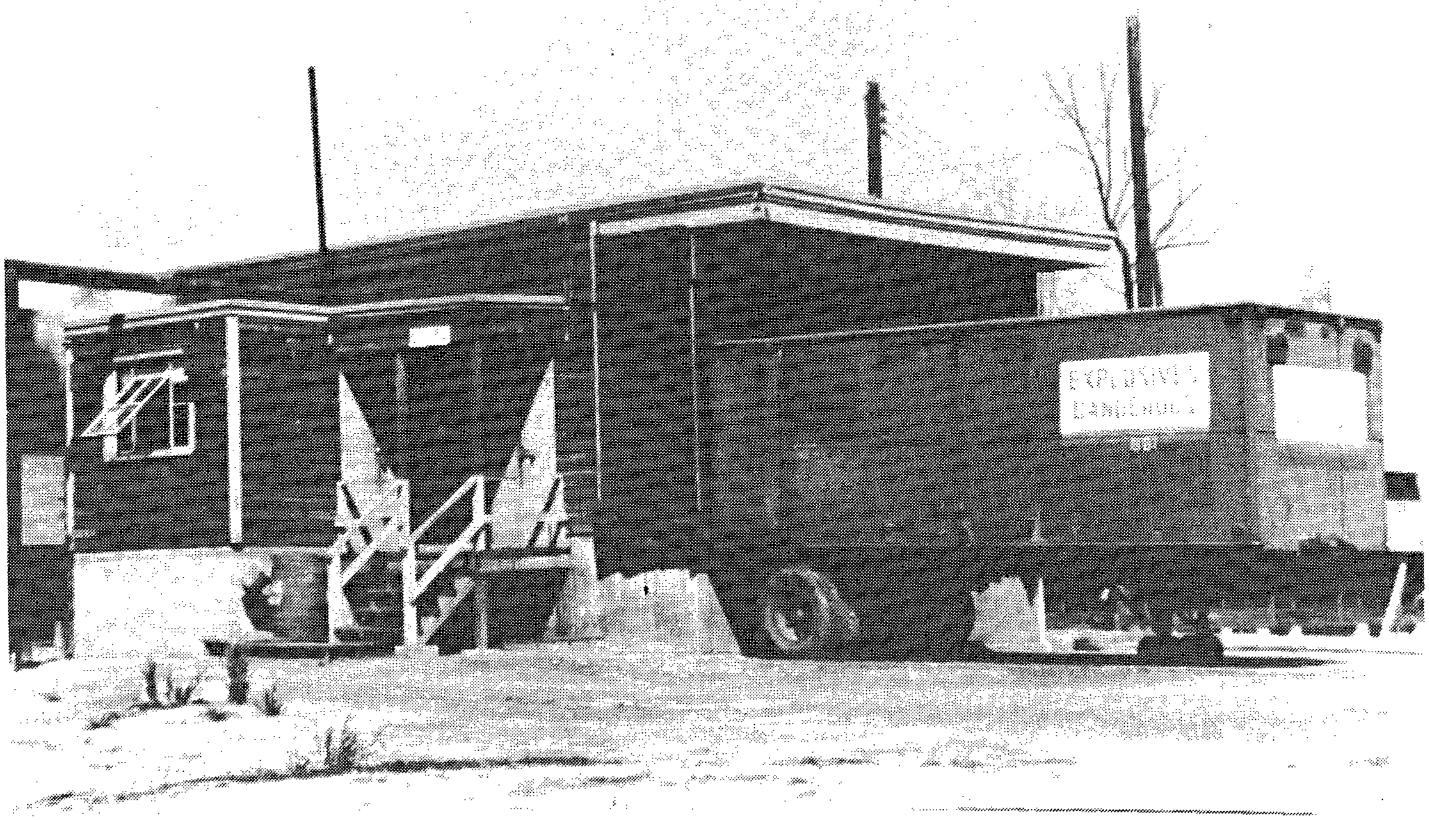


Figure 33. TNT Storage, K Building, Area B (courtesy of Holston AAP Photo Set No. 24-B [on file Engineering Vault, Building 26]).

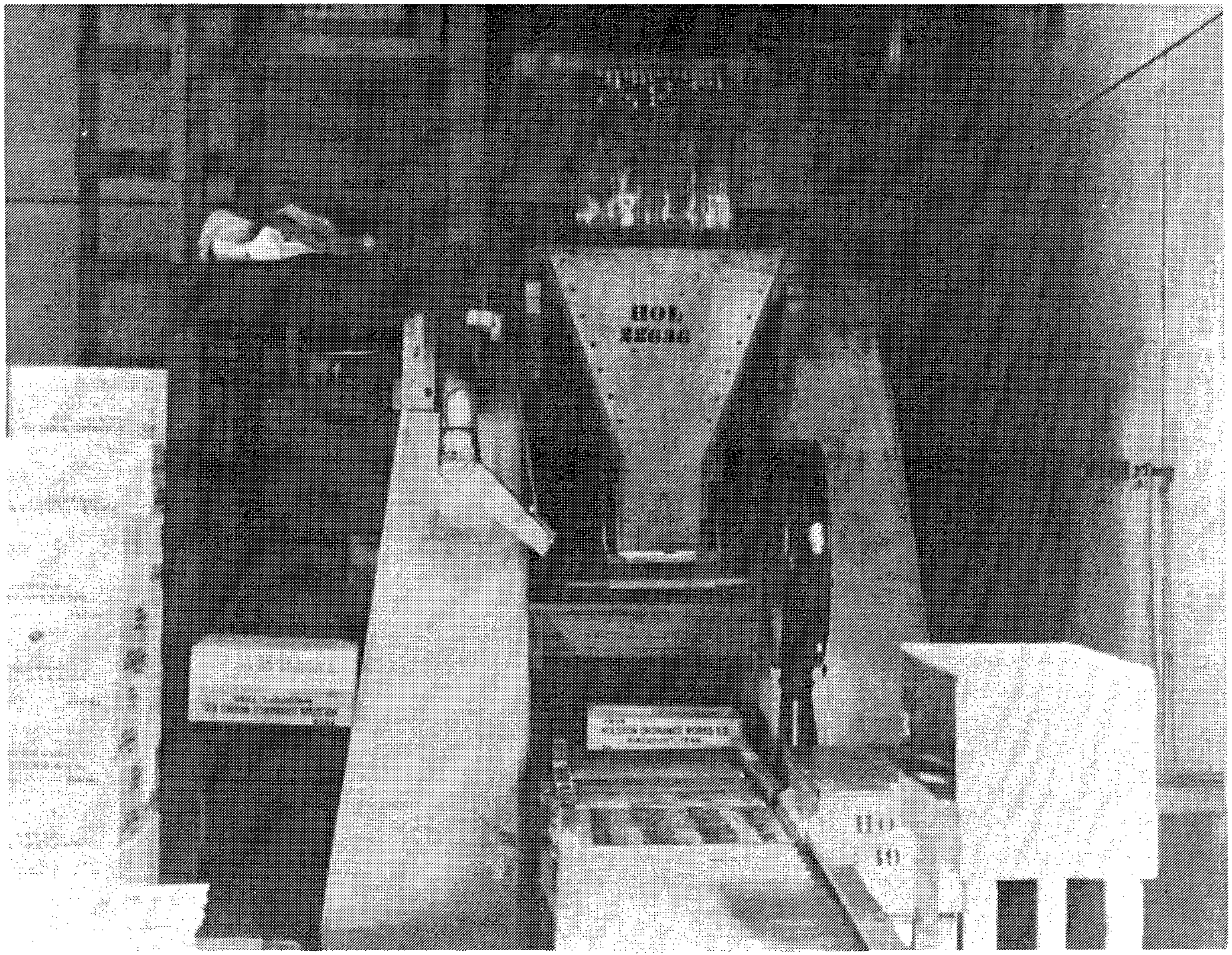


Figure 34. Composition B pellets leaving conveyor belt, Incorporation Buildings (courtesy of Holston AAP [on file Historical Files, Thomasson, Building 26]).

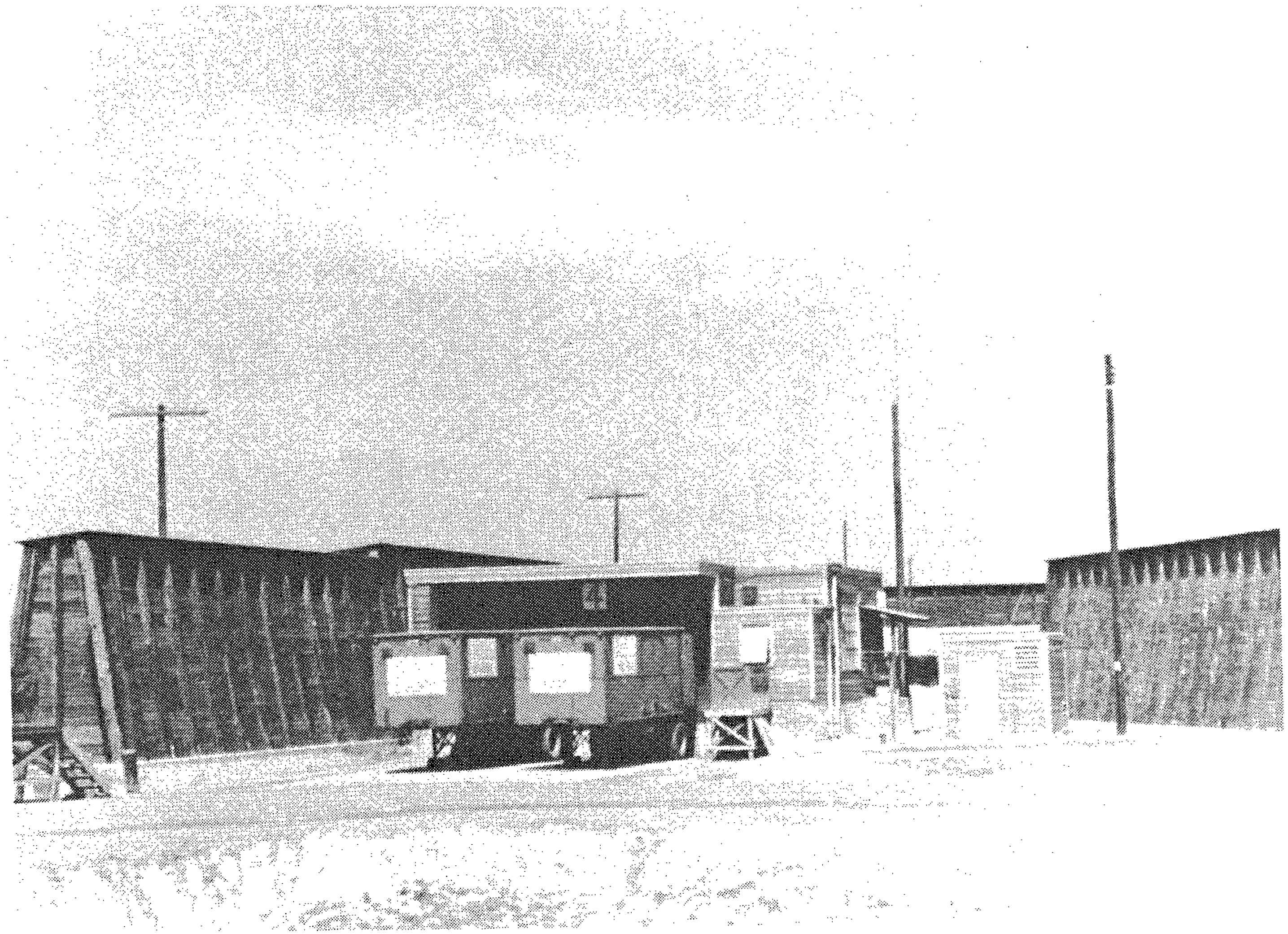


Figure 35. Nailing, N Building, Area B (courtesy of Holston AAP Photo Set No. 26-B [on file Engineering Vault, Building 26]).

Figure 36. Interior, N Building (courtesy of Holston AAP Photo Set No. 26-B [on file Engineering Vault, Building 26]).

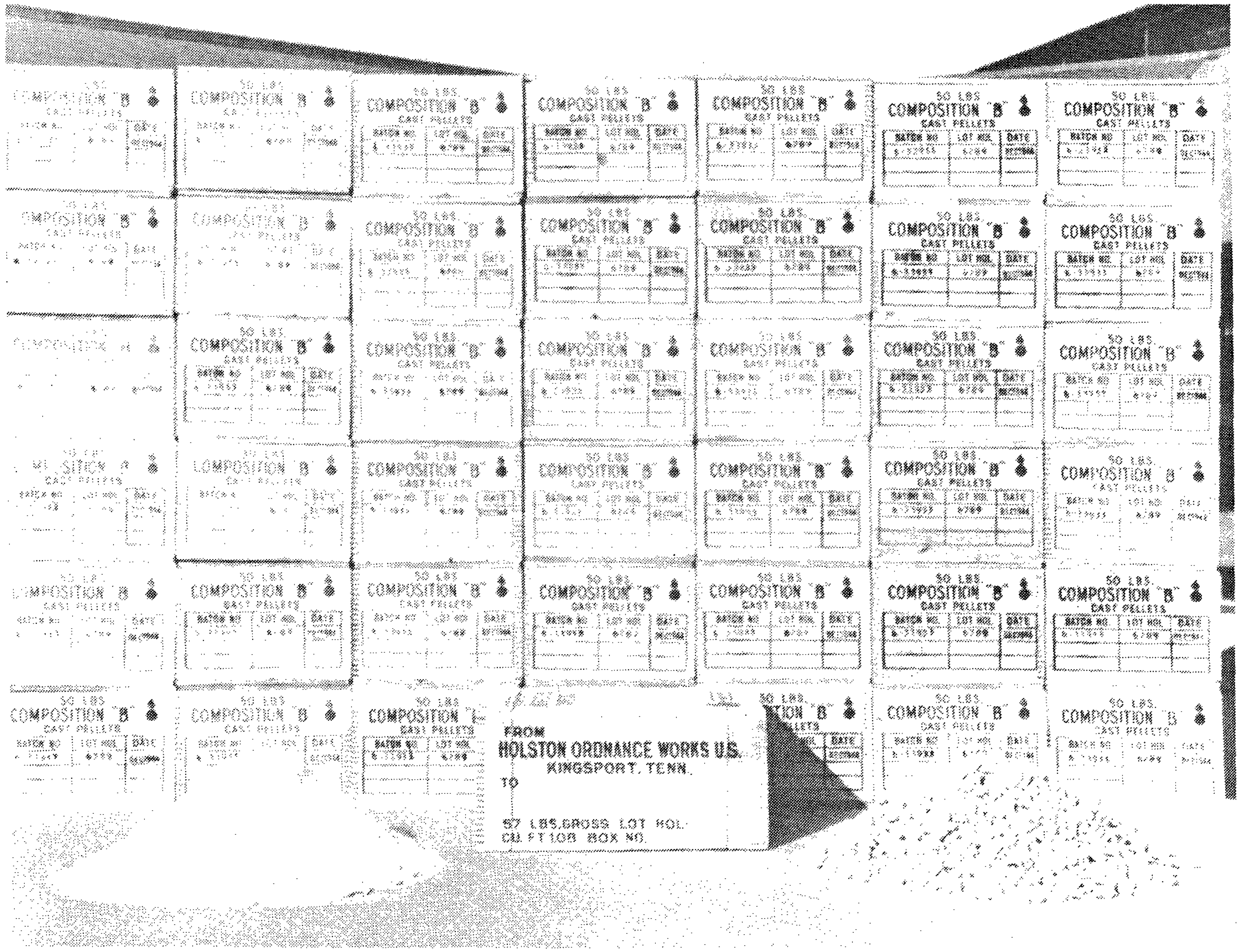


Figure 37. Composition B ready for shipment (courtesy of Holston AAP [on file Historical Files, Thomasson, Building 26]).

particularly the case for Composition B, which was essentially made by the batch method, not continuous feed, and had a relatively high labor cost and low production yield. By the end of the war, Lee Davy had produced a report on RDX manufacturing problems and their potential solutions (L.G. Davy 1945). In this report, he listed the four problem areas in RDX and Composition B production: recrystallization of RDX; problems in making the process completely continuous; solutions; and the nitration of hexamine. Lee Davy (1945) had recommended that Composition B be produced by continuous feed method, but this was never implemented during the war.

The biggest change that did occur in the whole process was the way in which hexamine was nitrated. Essentially, this entailed changes to the 503 Area (nitric acid) which had always been the weak link in the Holston process. Nitric acid, unlike acetic acid and acetic anhydride, had not been a specialty of TEC before the war. TEC had borrowed its nitric acid technology directly from Hercules and DuPont. The 503 Area was modified throughout the war to improve the nitric acid and ammonium nitrate portion of the nitration process.

By August of 1944, Building 330 had been added to the 503 Area (Figure 38). Known as the Ammonium Nitrate Manufacturing Plant, or the Nitric Acid-Ammonium Nitrate Plant, Building 330 provided Holston with its own supply of ammonium nitrate, heretofore bought from outside vendors (MacDonald and Mack 1984:28-38). After August 1944, the 503 Area produced a mixture of ammonium nitrate and nitric acid, and supplied that mixture to the C buildings. In the final year of the war, the procedure in the 503 Area was as follows. Ammonia, bought from outside venders, was first stored in Building 301, the ammonia storage tank farm. From there, it went to Building 302 or 302B, ammonia oxidation buildings, where the ammonia was turned into oxides of nitrogen (Figure 39). This material was then sent to Building 312, the absorption towers, where the oxides of the nitrogen, plus water, were transformed into 60 percent nitric acid. During World War II, the 60 percent nitric acid was sent to the sulfuric building (Building 303, now gone), for distillation into 99 percent nitric acid. The 99 percent nitric acid was then sent to Building 330, the ammonium nitrate manufacturing plant, where it was combined with ammonia to produce the ammonium nitrate-nitric acid solution that was shipped to the C buildings.

Despite this improvement to the process, it would appear that the new Ammonium Nitrate Plant had its share of problems. Later in the war, whenever there was a shortage of nitric acid, the plant was often furloughed. Ammonium nitrate was then purchased from vendors (MacDonald and Mack 1984:37-38).

The last war-time addition to the process was made in the spring and summer of 1945, when Building 303B was added to the 503 Area (Figure 40). Known as the Magnesium Nitrate-Nitric Acid Concentrating Plant, it was essentially a pilot plant for dehydrating nitric acid to 99 percent-strength by using magnesium nitrate rather than sulfuric acid. Although the war ended before this pilot plant could be put to general use, it paved the way for the magnesium nitrate dehydrating towers, known as "maggie units," which became a part of the Holston process during the 1950s (Johnson, interview 1995; MacDonald and Mack 1984:28-33, 38).

Significance to the War Effort

Holston Ordnance Works, believed to be the largest single producer of RDX and Composition B during World War II, represented a major innovation in ordnance manufacture. Mass production of RDX was perfected at Holston, using the continuous feed process championed by Tennessee Eastman. In this process, the raw materials needed to make RDX were held in semi-fluid form throughout production, with materials piped from one building to the next, rather than loaded and unloaded dry, as was commonly done with the batch process. Just as revolutionary was the recovery of production acids and other raw materials in the B Buildings and Area A. Another remarkable feature was the "pellet process," whereby Composition B passed through special equipment and was dropped onto a conveyer belt in the form of "Hershey Kisses." This allowed for the fast production, cooling, and packing of Composition B. Not only was it safer, but it also saved space, time, and labor over previous methods (Englander 1946:16; Kane 1995:171-172).

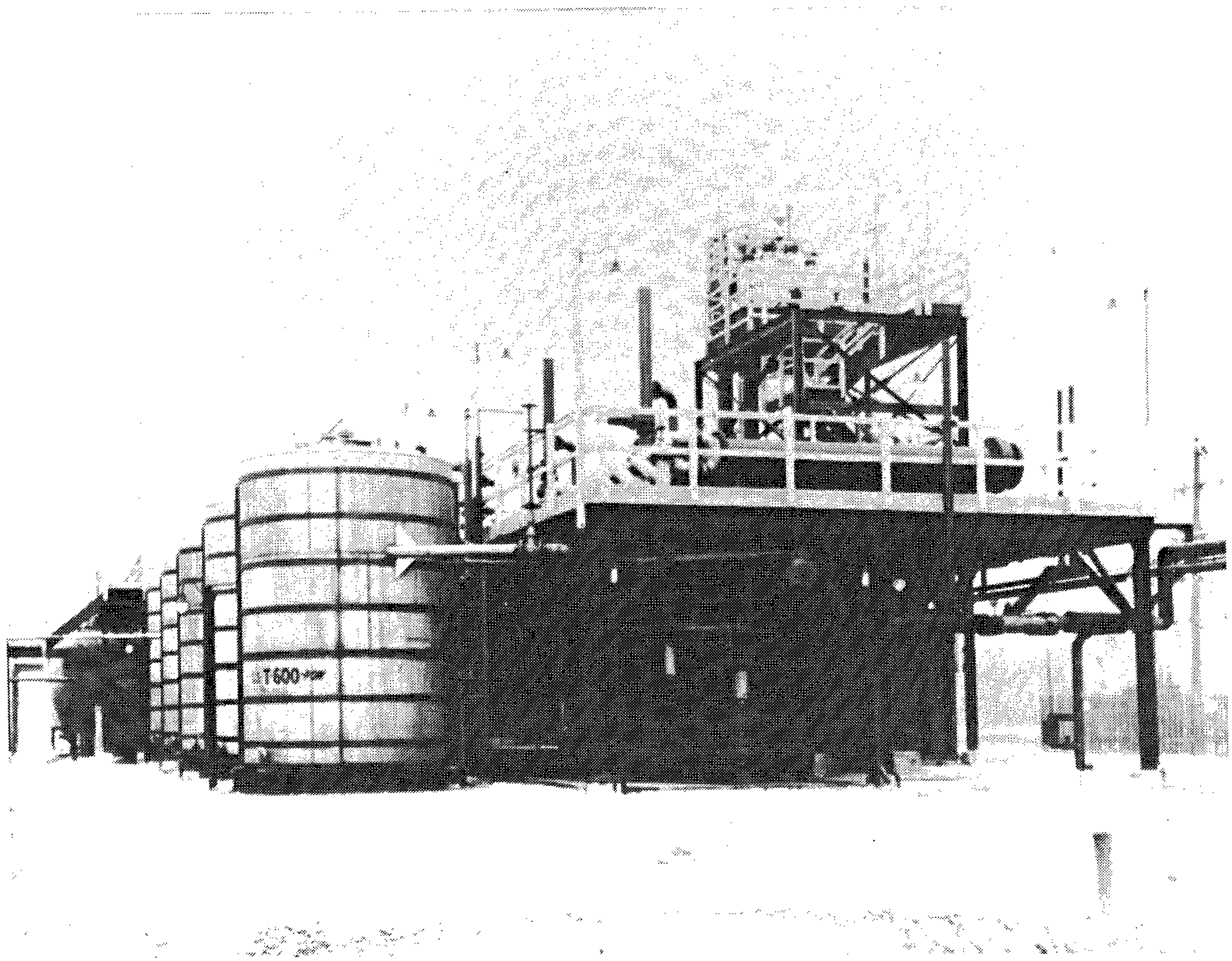


Figure 38. Ammonium Nitrate Manufacturing Plant, Building 330, 503 Area (courtesy Holston AAP [on file Engineering Vault, Building 26]).

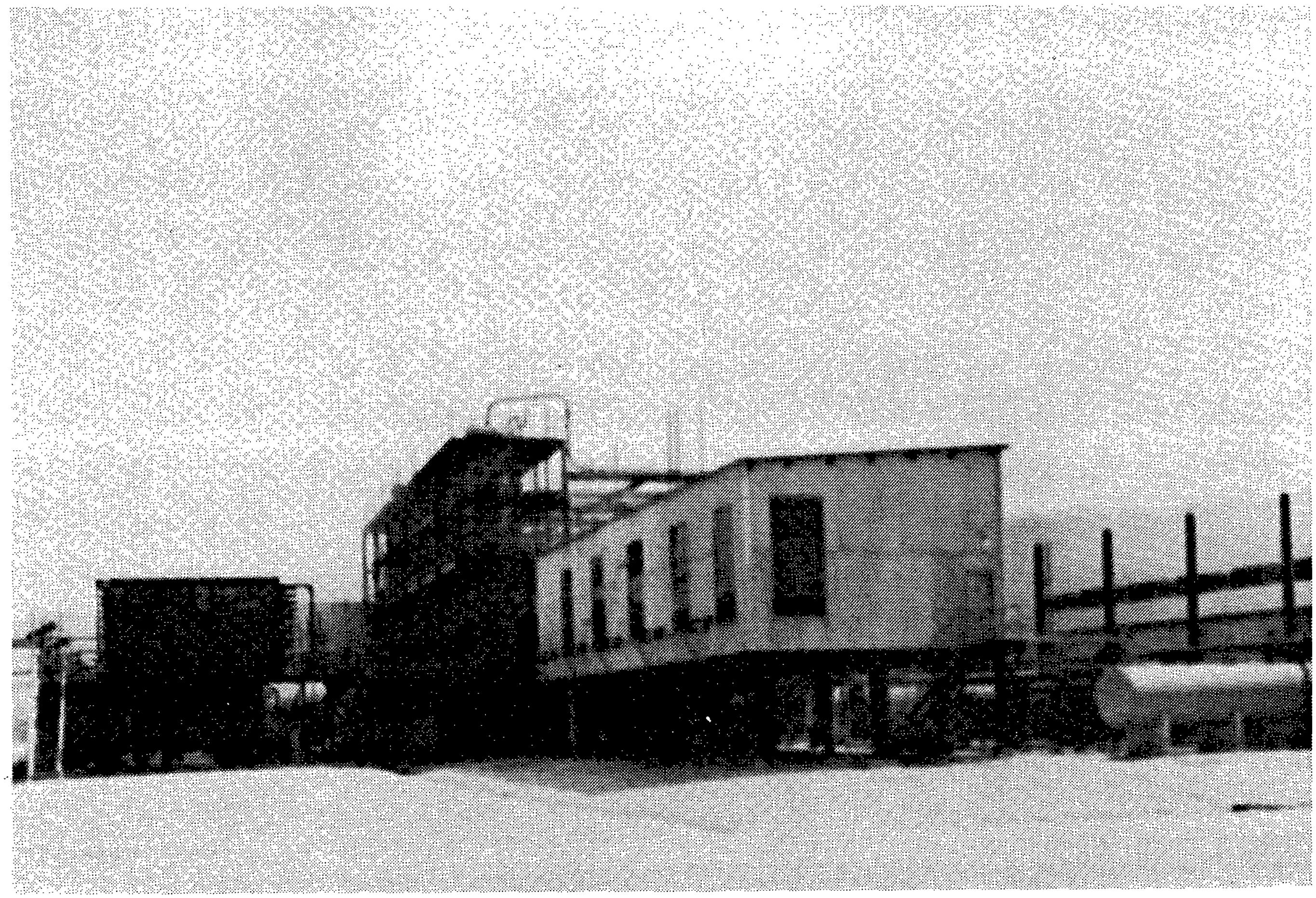


Figure 39. Ammonia Oxidation, Building 302, 503 Area (courtesy of Holston AAP Photo Set No. 32-B [on file Engineering Vault, Building 26]).

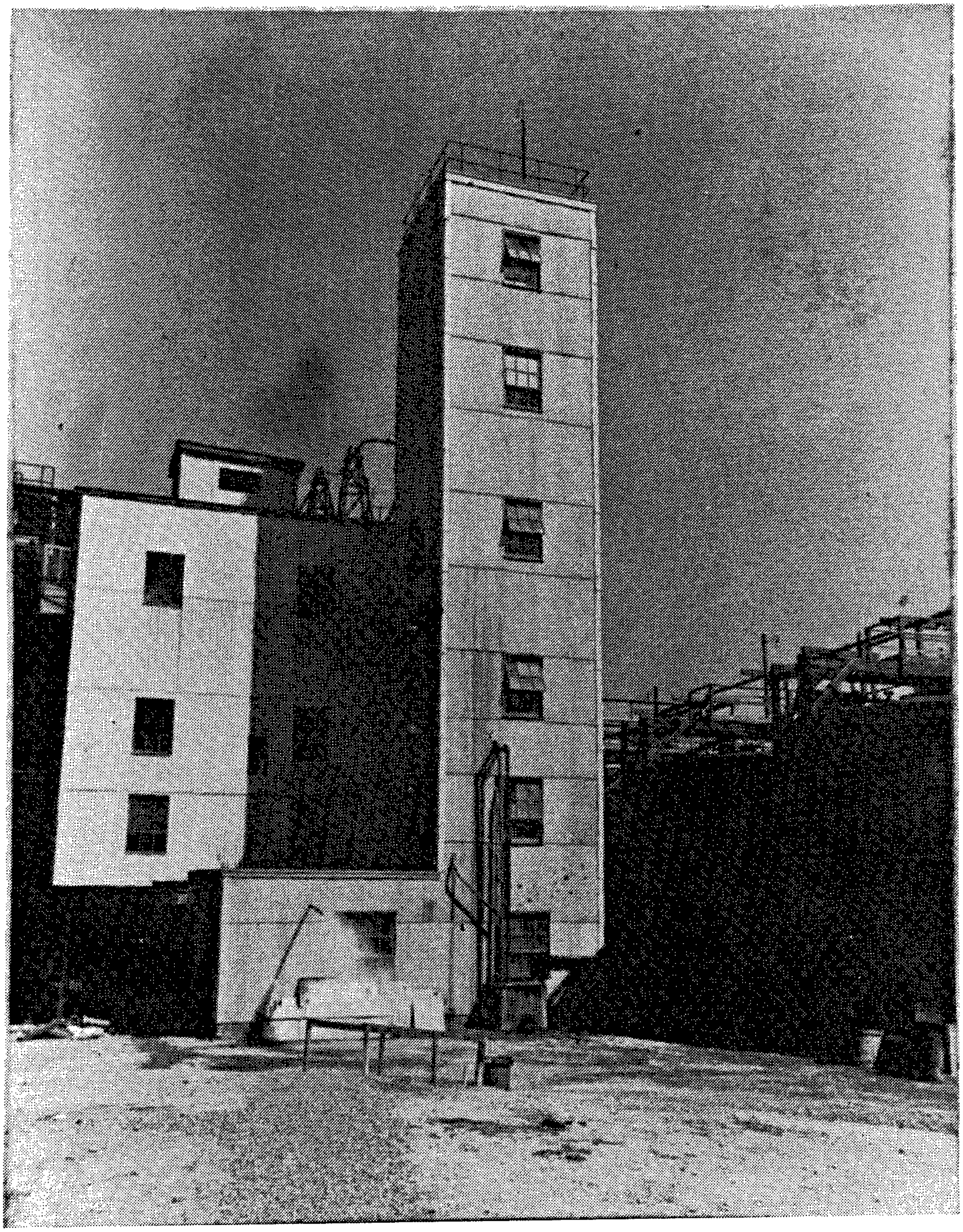


Figure 40. Nitric Acid Concentrator Pilot Plant, Building 303-B, 503 Area (courtesy of Holston AAP [on file Engineering Vault, Building 26]).

More important than all these production features, however, was the feat of production itself. RDX was in such demand in the early days of the war that the limited quantities produced in the TEC pilot plants went directly to the war effort, especially for use against German U-boats. RDX gave the Allies a fighting chance during 1942, the bleakest year in the Battle for the Atlantic, although it was not until May of 1943 that the Germans finally began to lose more submarines than they could produce. By June, the German admiralty realized that they had lost their advantage, and in the months that followed, the German U-boat campaign collapsed (Crawford 1945). By the summer of 1943, the vaunted U-boat fleet was only a shadow of its former self, and could not check the flow of men and materiel from the United States to Britain. The mass production of RDX and Composition B at Holston, beginning in the month of May 1943, is believed to have had a direct impact on the course of events connected with the Battle of the Atlantic. Holston produced an estimated 90 percent of the nation's Composition B, and it was in May that, for the first time, the U.S. naval forces had sufficient supplies of it to finally turn the tide of battle (Crawford 1945).

In the last half of the war, RDX was commonly used in aerial bombs, including the famous "blockbusters" (Crawford 1945). It was also found to be particularly effective against concrete fortifications. By the end of the war, it was estimated that RDX went into about 40 percent of all general purpose bombs (Green et al. 1990:463).

The development of RDX also led to the development of other powerful explosives, such as minol, tritonal, PETN (pentaerythritol tetranite), and EDNA (or haleite). Minol and tritonal were explosives enhanced with the addition of aluminum. PETN, highly unstable, was researched at NDRC laboratories and at Picatinny throughout the war. Finally, it was combined with TNT to form "pentolite," used in detonators, bazooka rockets, rifle grenades, and anti-tank shells. EDNA, largely developed by and later named for George Hale, chief chemist at Picatinny, was slightly less powerful than RDX, but much easier to handle. Production expenses, however, prohibited its use during the war (Green et al. 1990:464, 366-368).

SOCIAL HISTORY

Land Acquisition and Local Planning Era

Government Land Acquisition and Local Reaction

Tennessee Eastman was informed of plans to build Holston Ordnance Works on 6 June 1942. These plans were announced locally the following day, with subsequent announcements continuing on through June 11th (*Kingsport Times* 1942a). At that time, it was determined that Area A would be located near TEC headquarters in Kingsport, Sullivan County, while the much larger Area B would be situated four miles to the west, in rural Hawkins County.

Announcement of the new plant was greeted with enthusiasm throughout the Kingsport area, both for patriotic and economic reasons. As a result, there were few, if any, problems in acquiring the land needed for Holston. This was particularly true for Area A, which was to be located on land that was already industrial in nature. There were people that had to be displaced in Area B, but they were relatively few in number, and there is no record of any problem in acquiring the land.

Area B occupied some 6,370 acres three miles west of Kingsport, immediately south of Highway 11-W (Figure 41). The land was almost equally divided by the Holston River, which ran roughly east to west across the property. Most of the individual holdings were small farms ranging in size from just a few acres to a couple of hundred acres that were located in the west half of the tract. Tobacco appears to have been the main cash crop, and there was at least one small dairy in this area, owned by Mary C. Kenner (Tract B-230).

The three largest holdings, located to the east and south, were well over 1,000 acres, and together they comprised the majority of Area B. Two of these embraced all of Area B south of the Holston River (Tracts B-226 and B-227), and both were farms that produced tobacco and corn. The largest of the three tracts (B-236), a dairy farm owned by John B. Dennis and valued at around $200 per acre, was located on the north side of the river (Collins, interview 1995). From all indications, the government paid the going rate for this 1,602-acre tract.

At the time of acquisition, there were 67 buildings on the Dennis dairy. Thirty-two of these were standing, at least during the initial period of construction (Plant A and B, Reservation and Tract Map 1943). One of these was the Rotherwood House (B-236-1), which immediately became the home of Holston commanding officer, Lt. Col. William E. Ryan (*Kingsport Times* 1942b). Other staff quarters were soon built in this area, which came to be known as Rotherwood Estates.

All of the structural features and improvements to the area were mapped prior to acquisition and are depicted on the land acquisition map (see Figure 41). With a few exceptions, such as the Rotherwood House, these structures are no longer extant. At the time of acquisition, there were three small cemeteries located in Area B. The smallest was the N. E. Walters Cemetery (B-242C). It occupied 0.01 acres in the west half of Area B adjacent to the highway. The other two were adjacent to the Rotherwood House in the northeast corner of Area B. Identified on the government map as B-236C and B-236D, these were the Phipps and the Doe cemeteries, respectively. Each occupied one-tenth of an acre (Plant A and B, Reservation and Tract Map 1943).

Two of the barns on the Dennis dairy farm were used by Fraser-Brace during the initial construction phase. One became construction headquarters, while the other served as a temporary cafeteria for workers (Stauffer, interview 1995).

Boomtown and Local Planning

By the time Holston Ordnance Works was announced, the United States had been at war for half a year. Holston was one of the last munitions plants to be built, and it was constructed during a time of serious material shortages and delays. It was probably for this reason that there was only limited boomtown construction in the Kingsport area in preparation for Holston. The barracks constructed in Area B held a relatively small number of people, and war-time housing in Kingsport was not completed until months after construction began on Holston. Most of the new construction workers either commuted to work or lived in every available space in Kingsport.

With the lack of new housing, Kingsport was overcrowded during the first months of the Holston construction phase. Municipal authorities urged town residents to cooperate by providing housing for the newcomers. Despite the lack of time and resources allowed for municipal preparations for the Holston influx, the transition went remarkably well. This is especially surprising considering that over 15,000 construction workers were employed at Holston at the height of the construction period, which was more than the number of permanent residents in Kingsport before the war.

Construction Era

Construction Workers

When Holston was still in the planning stages, it was estimated that it would take between 15,000 and 20,000 workers to complete construction of the facility. This estimate was not far off from the actual number of

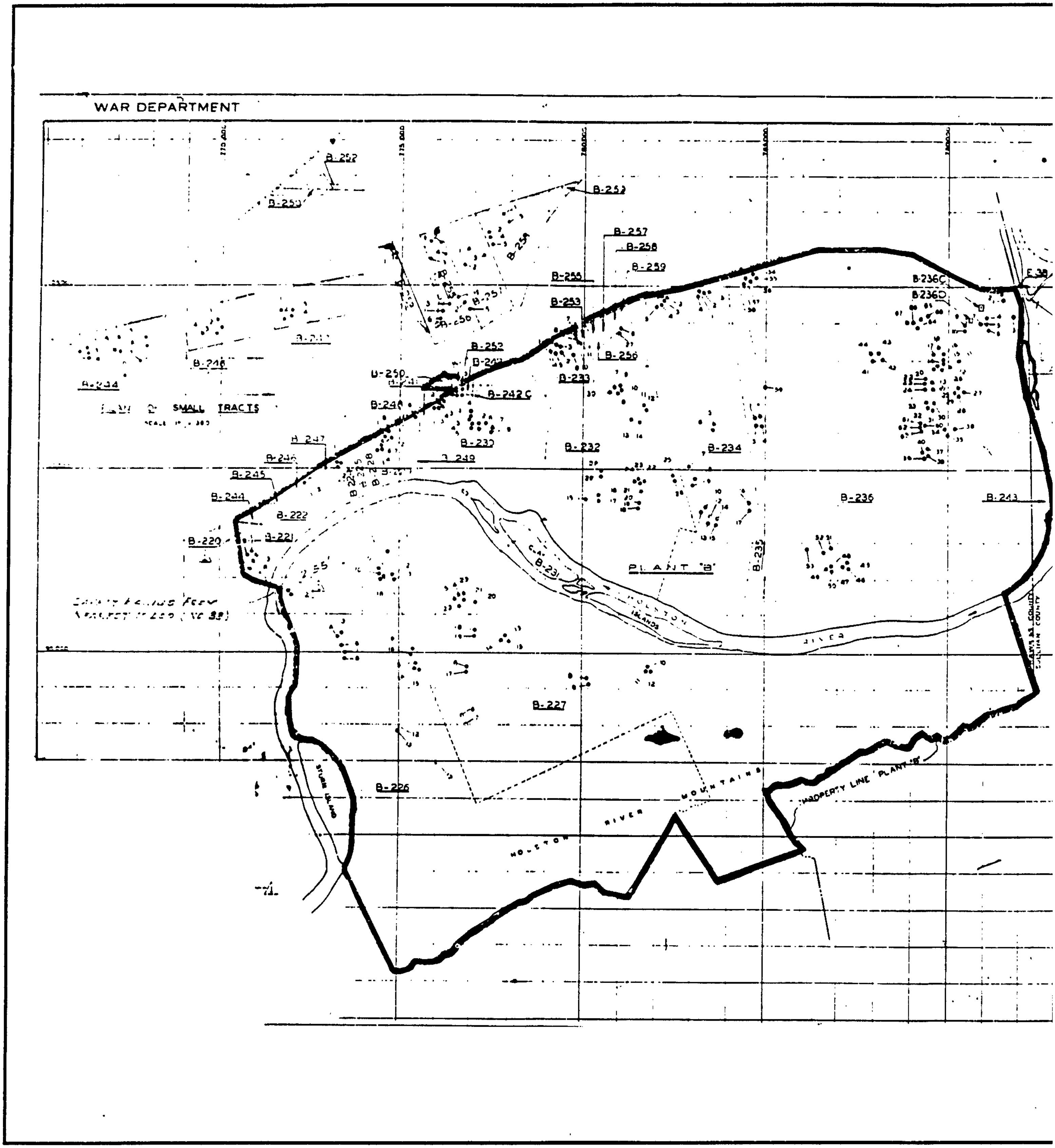
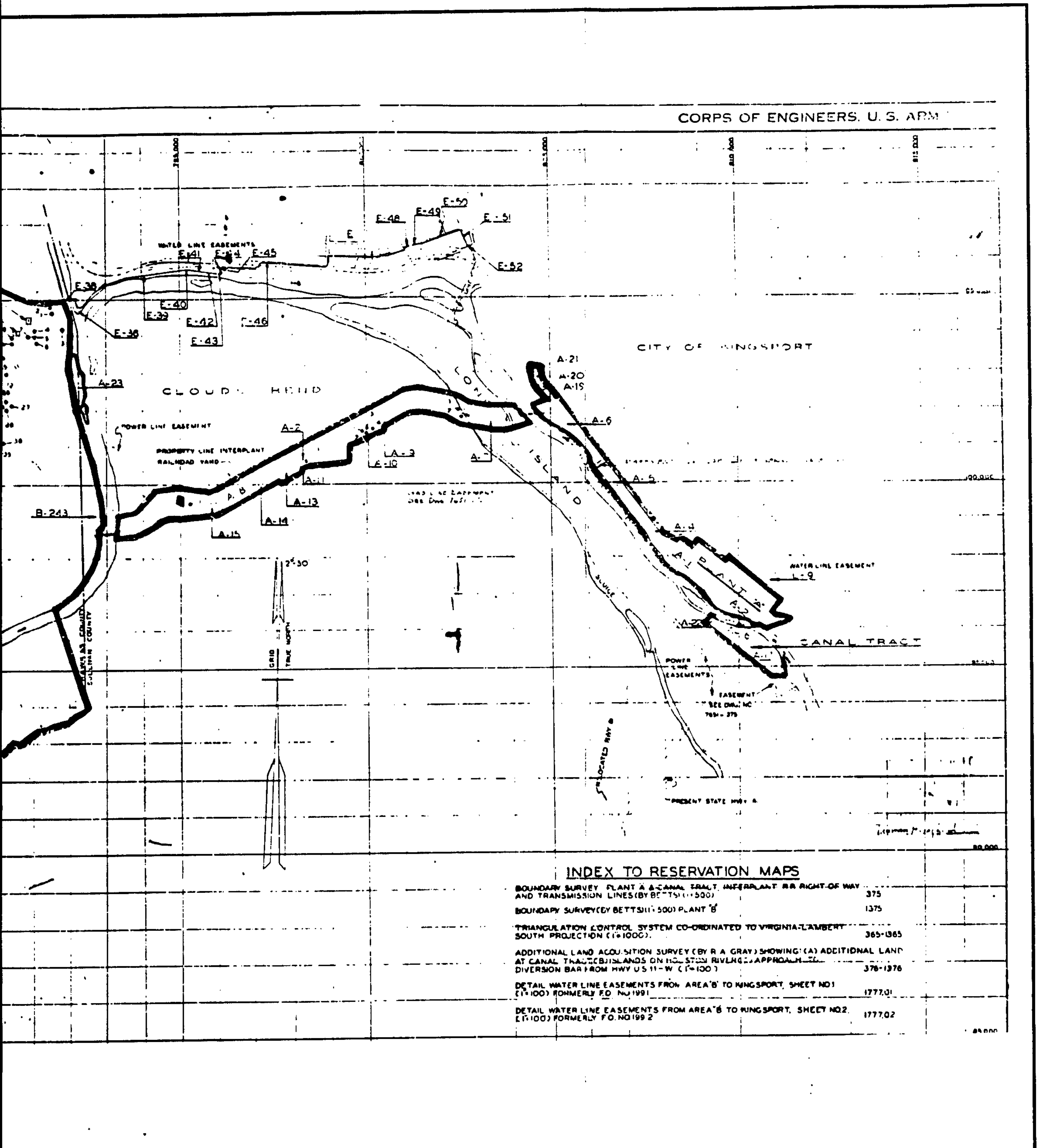


Figure 41. Land acquisition map, Holston Ordnance Works, showing pre-war owners and structures (Plant A and B, Reservation and Tract Map 1943).


CORPS OF ENGINEERS. U. S. ARMY
E-48
E-49
E-50
E-51
E-52
E-45
E-38
E-40
E-39
E-42
E-46
E-36
E-43
WATER LINE EASEMENTS
CITY OF KINGSPORT
A-21
A-20
A-19
A-23
CLOUDS HEAD
POWER LINE EASEMENT
PROPERTY LINE INTERPLANT RAILROAD YARD
A-2
A-9
A-10
A-6
A-5
A-11
A-13
A-14
A-15
B-243
ISLAND
A-4
WATER LINE EASEMENT
L-9
PLANT A
SLUICE
CANAL TRACT
POWER LINE EASEMENTS
GRID NORTH
TRUE NORTH
HAWKINS CO.
SULLIVAN COUNTY
RELOCATED HWY
PRESENT STATE HWY
INDEX TO RESERVATION MAPS
BOUNDARY SURVEY PLANT A & CANAL TRACT, INTERPLANT RR RIGHT-OF-WAY AND TRANSMISSION LINES (BY BETTS) (1"=500) 375
BOUNDARY SURVEY (BY BETTS) (1"=500) PLANT "B" 1375
TRIANGULATION CONTROL SYSTEM CO-ORDINATED TO VIRGINIA-LAMBERT SOUTH PROJECTION (1"=1000). 365-1365
ADDITIONAL LAND ACQUISITION SURVEY (BY R A GRAY) SHOWING: (A) ADDITIONAL LAND AT CANAL TRACT (B) ISLANDS ON HOLSTON RIVER (C) APPROACH TO DIVERSION BAR FROM HWY U S 11-W (1"=100) 376-1376
DETAIL WATER LINE EASEMENTS FROM AREA "B" TO KINGSPORT, SHEET NO 1 (1"=100) FORMERLY F.O. NO 1991 1777.01
DETAIL WATER LINE EASEMENTS FROM AREA "B" TO KINGSPORT, SHEET NO 2 (1"=100) FORMERLY F.O. NO 1992 1777.02

act Map 1943).

construction workers employed. By the end of August 1942, there were 6,000 construction workers employed by Fraser-Brace; a month later, there were 10,000. By the early spring of 1943, the number of construction workers peaked at over 16,000, which did not include subcontractors, the architect-engineering people, War Department personnel, and the operating staff. As the official Fraser-Brace report suggested, the size of the Kingsport labor force was completely inadequate for this task (Englander 1946:17).

Fraser-Brace estimated that the local labor force contained some 3,000 to 4,000 common laborers, with skilled laborers numbering in the hundreds. It was clear from the beginning that most of the labor force for Holston would have to be culled from a very large surrounding area and that the majority would have to commute to work since there was little available room in Kingsport (Englander 1946:17-18).

As it turned out, most construction workers did commute, but a fair number resided in Kingsport. Rooms, porches, even bed-space were rented out by local residents who were urged to provide as much rental space as they could afford. From most indications, Kingsport residents were gracious to the newcomers who, in turn, were tolerant of the crowded housing situation.

Construction workers were attracted from all over Tennessee, Virginia, Kentucky, and North Carolina. Most Holston workers, however, commuted within a much smaller radius, that was bounded to the northwest by Cumberland Mountain and to the southeast by the high peaks of the Appalachians and the Blue Ridge. In effect, this area encompassed northeast Tennessee and southwest Virginia.

Most of the available work force in this area was of Scotch-Irish, English, or even German descent, and their ancestors had been in the region for over 150 years. There were few recent immigrants. There were also relatively few African-Americans, most of whom resided in the cities. Only five percent of Kingsport's population was African-American during the 1940s (Wolfe 1987:8). No figures have yet come to light on the ethnic breakdown of construction personnel hired by Fraser-Brace, but it is probable that few identifiable minorities were hired to build Holston Ordnance Works.

Effects of Construction on Community Infrastructure

The construction of Holston Ordnance Works had an immediate effect on the community of Kingsport. In 1940, the city had a population of some 15,000. By 1942, it had risen to just under 20,000 in response to the industrial development of the area and the growth of Tennessee Eastman. By 1943, as a result of Holston, the population of Kingsport ballooned to 60,000 (Englander 1946:18).

Even before the war, Kingsport was overcrowded, and the construction of Holston only made this matter worse. Fraser-Brace suggested three solutions to the housing crisis: barracks at the project site; temporary family housing; and construction of new, permanent housing in Kingsport (Englander 1946:18). In mid-1942, however, it was difficult to implement these solutions since most other GOCO construction was in full swing and construction materials were in short supply (Kane 1995:86).

The lack of local housing had become a serious issue by July of 1942. Kingsport mayor, Glen Bruce, led efforts to improve matters with the creation of the "Emergency Housing Authority," which was established at the corner of Broad and Center streets. Since new construction on a large scale was impossible at such a late date, citizens were urged to rent all available spaces to construction workers so they would not have to commute. Citizens were also urged not to gouge workers, and local steps were taken to keep rent under control (*Kingsport Times* 1942c).

Mayor Bruce and the Kingsport Merchants Association were instrumental in setting up the City Housing Program, organized on 1 August 1942. One of the first acts of this program was to conduct a thorough house-by-house survey of the city and environs to determine the location and status of all possible rental

space in the Kingsport area (*Kingsport Times* 1942d). People canvassed the countryside within a 50-mile radius of the city to locate potential housing. In some cases, people were offered money to fix up old buildings at government expense (Caldwell 1988).

Between June and September 1942, Fraser-Brace constructed barracks at Area B for workers who could not afford rent in town (Englander 1946:18). In September, old Civilian Conservation Corps camp barracks from Marion, Virginia, were brought to the work site to house an additional 1,000 construction workers. Much of this work was supervised by Major Elvin Gates, the Army Corps of Engineers officer in charge of construction (*Kingsport Times* 1942e; Necessary, personal communication 1995). The government also operated a trailer camp for some 300 families and additional trailer camps soon opened in and around Kingsport (Englander 1946:18). One of these occupied a six-block site on Market Street, consisting of some 200 government-owned trailers (*Kingsport Times*, photo, 23 October 1942).

Because of the limited availability of building materials, permanent housing construction was slow to get started and had little impact on the construction phase of Holston. By the time new permanent housing was available, most of Holston was already completed (Report on Administrative Problems 1945:8). New housing construction began in August of 1942, after the plans were approved by the National Housing Agency and the War Production Board. The new dwellings were to be built along established transportation lines and within a reasonable walking distance (two miles) of the facility. Plans called for 315 new units, constructed by private contractors. Two-hundred-and-twenty-five of these new units were to be rented, with 185 rental units going for \$37-40 a month, and 40 units renting for \$40-50. The remaining 90 units were to be sold for between \$4,000 and \$6,000 (*Kingsport News* 1942). A 6 November 1942 update on this construction project identified the private contractor as W. K. Johnson, of Kingsport Defense Homes, Inc. Under construction in the Winston Terrace area of town, the houses ranged in size from four-and-one-half to six rooms each. It was anticipated that the smaller houses would rent for \$43.50 a month; the larger, for \$54.50 (*Kingsport Times* 1942f). Scheduled for completion sometime between 1 January and 1 June 1943, the houses would be finished long after the bulk of Holston Ordnance Works had been built.

In addition to permanent housing, there was also an increase in service facilities. Relatively little data on the expansion of service facilities in Kingsport exist, but it is known that local bus service increased dramatically in July and August of 1942. City Transportation, Inc., of Kingsport, expanded its bus fleet from seven to 20 vehicles, while five new regular routes were added to the lines already established. Most of these new lines included stops at Holston and Tennessee Eastman (*Kingsport Times* 1942g).

In addition to bus service, medical services expanded. The construction of a brick hospital in Area B was announced at the end of September 1942. This facility was to be staffed by three to four doctors and 15 nurses, with an average capacity of 13 patients (*Kingsport Times* 1942h).

Effects of Construction on Local Economy

From the beginning, local citizens were urged to limit their profits from the Holston influx; rent hikes were denounced as unpatriotic (*Kingsport Times* 1942i). In October of 1942, the federal Office of Price Administration decreed rent control for certain areas essential to the war effort, including Kingsport. Rent was turned back to levels that were in effect on 1 March 1942 (*Kingsport Times* 1942j).

By November of 1942, with nearly 15,000 workers employed at Holston, life in town meant waiting in line. To accommodate the unusual hours required of different Holston construction work shifts, local businesses began to maintain longer hours (*Kingsport Times* 1942k). In addition to waiting, there were other war-time inconveniences to be endured. On 9 June 1942, there was a state-wide blackout, with another scheduled for October (*Kingsport Times* 1942l). The 40-mile-per-hour speed limit was also closely enforced (*Kingsport Times* 1942m).

Despite these problems, however, it would appear that Holston was beneficial to the local economy, especially after the frantic first few months. Retailers, restaurant owners, and businesses all benefited from increased customer volume. By the end of the war, small fortunes had been made in many businesses, including the housing industry, as local construction companies struggled past rationing and labor shortages to complete the housing required by the new facility.

Organized Labor

Traditionally, east Tennessee has not been receptive to organized labor, and this was certainly the case in Kingsport where local business leaders frowned on labor unions and worked to keep them out. Workers, hungry for jobs, were not eager to call them in. Before the war, Tennessee Eastman had thrived in this business climate; no union was allowed to gain a toe-hold at TEC. This attitude was carried over into the administration of Holston, which was staffed by TEC personnel. During the operation of Holston, no union activity was allowed on the premises, and union organizers within the work force were dismissed as soon as their activities became known (Collins, interview 1995). Alternatively, Fraser-Brace, the New York-based company that constructed Holston, was unionized, and is believed to have been the only major company associated with the construction and operation of Holston that allowed organized labor (Stauffer, interview 1995).

Wartime Operation Era

Employment Numbers

The role of Fraser-Brace ended in March of 1944, but prior to that Holston had its own employees on the scene, preparing the plant for production and operation. Plant operation began with line 1 on 8 May of 1943. In rapid succession, other lines became operational. By September 1943, when Melvin Johnson came from Michigan Tech to work at Holston, there were at least five to six lines in full swing (Johnson, interview 1995).

Many of the Holston chemical engineers transferred from Tennessee Eastman. The Eastman Kodak Company in New York also contributed trained personnel (Report on Administrative Problems 1945:1). Others, like Melvin Johnson, were hired right out of school. The services of all these people were so vital to the munitions industry that there was little chance of their being drafted. Many others, often without any technical schooling, were hired and trained for their particular assignment. Their status with the draft boards was more problematic, and Holston had to wage a constant campaign to keep its lower echelon employees out of the war.

Despite these problems and subsequent alteration to the production lines, RDX manufacture continued without a break until V-J Day. Production continued around the clock, seven days a week, with workers laboring in three 8-hour shifts (Caldwell 1988). To meet this rigorous schedule, the initial work force of 200 employees in the summer of 1942 increased to more than 6,000 by 1944 and 1945.

The work force at Holston fluctuated throughout this period, depending on the construction progress of Fraser-Brace and the facility's own production needs. A brief sketch of the employment figures over time includes:

August 1942	c. 400 employees (HOW 1943d:VII:Exhibit 11)
September 1942	c. 800 employees (HOW 1943d:VII:Exhibit 11)
October 1942	c. 1,000 employees (HOW 1943d:VII:Exhibit 11)

November 1942	c. 1,200 employees (HOW 1943d:VII:Exhibit 11)
February 1943	c. 1,400 employees (HOW 1943d:VII:Exhibit 11)
March 1943	c. 1,600 employees (HOW 1943d:VII:Exhibit 11)
April 1943	c. 2,000 employees (HOW 1943d:VII:Exhibit 11)
May 1943	2,413 employees (HOW 1943b:V:5)
July 1943	3,858 employees (HOW 1943d:VII:6)
August 1943	4,585 employees (HOW 1943d:VIII:5)
September 1943	5,147 employees (HOW 1943d:IX:9)
December 1943	5,989 employees (HOW 1943a:XIII:Exhibit 8)
January 1944	6,146 employees (HOW 1944d:I:97)
March 1944	6,830 employees (HOW 1944d:I:16)
May 1944	6,818 employees (HOW 1944a:V:6)
August 1944	6,245 employees (HOW 1944c:VIII:44)
September 1944	5,989 employees (HOW 1944c:X:54)
November 1944	5,750 employees (HOW 1944b:XII:35)
January 1945	5,583 employees (HOW 1945c:I:33)
April 1945	5,304 employees (HOW 1945a:I:35)

In the spring and summer of 1943, when Holston production lines went into operation, there was a substantial increase in employment figures. By September 1943, when most of the production lines were operational and most of the construction complete, Holston had an operating staff of over 5,000. This number would peak in March of 1944 with just under 7,000 employees, only later to decline in late 1944 and 1945. The staff reduction was due to improvements made in the manufacturing process. It took 123 workers to operate a production line in May of 1943. By 1944, this had been reduced to 100, even though production itself had doubled (Burton and McNeeley 1944:14).

Effects on Housing and Transportation

The operation of Holston had less of an impact on Kingsport than the construction of Holston did. The number of employees required to operate the plant was far lower than that needed by Fraser-Brace to build it. Additionally, Holston employees were able to take advantage of the new permanent housing that was finally completed in 1943. Thus, plant employees were less affected by housing shortages than were the construction workers. Built by Kingsport Defense Homes, Inc., most of the new dwellings were constructed with "speed brick" provided locally by the General Shell Company (Herring, interview 1995; HOW 1943b:V:6).

In the early days of the Holston operation, more than half the labor force had to commute over 20 miles to get to work. By 1945, only one-third were in this predicament. Public transportation and extensive car-pooling helped to alleviate the remaining transportation problems. The greatest problem remaining was gas rationing. Private car owners had difficulty obtaining enough ration coupons to keep themselves on the road. It was finally decided that Holston could set up its own board to determine gas rationing allowances (Report on Administrative Problems 1945:5-6).

By the end of 1943, the Holston employment pool lived within northeast Tennessee and southwest Virginia. Even though some workers had permanent addresses farther afield, all had temporarily moved to this general area. A full 5,076 employees out of a total of 5,989 Holston employees in December of 1943 resided in northeast Tennessee. The remaining 913 individuals commuted from Virginia (HOW 1943a:XIII:Exhibit 14).

Work Force Demographics

Out of the 6,146 people employed at Holston in January of 1944, a full 62 percent (3,799) worked in production. Twenty-two percent (1,347) worked in services and maintenance, while 8 percent (498) worked within industrial relations, which included everything from medical personnel to janitors. The remaining 8 percent (503) were employed in the General Office (HOW 1944d:I:97[Exhibit 16]).

As a rule, wages were calibrated according to position. The highest paid workers were the first-class machinists, electricians, and coppersmiths, all of whom were essential to production line operation and repair. They made approximately $1.10 an hour. Production line operatives made less, and janitors made less again (around $.60 an hour). At the bottom of the pay-scale were the General Office secretaries, stenographers, and record clerks, who earned between $0.30 and $0.40 an hour (HOW 1944a:IV:61).

Most of the labor force at Holston consisted of European-American males. There were relatively few African-Americans within the labor pool area, and fewer still employed at Holston. There were virtually no other minorities to speak of, either within the region or employed at Holston. There were, however, a sizable number of women employed at Holston. Forced into the labor market by the war-time shortage of available men, many of these women were employed for the first time. The following section deals with the employment of both African-Americans and women, relative newcomers to the job market.

Previous research on GOCO facilities around the country has suggested that the percentage of African-Americans working in the munitions industry increased from 3 percent in 1942 to 8 percent by the end of the war (Kane 1995:206). Much of this advance was driven by the need for additional labor during the war, and was achieved in the face of Jim Crow laws in the South and what was often general prejudice in the rest of the nation.

At Holston, there were relatively few African-American employees, and all were relegated to nonessential positions. No African-Americans were placed on the production lines, and, in the official records, they were not even counted with the rest of the employees. African-American employees numbered around 200, which was about 3 percent of the total work force (HOW 1944d:I:16). Efforts were made to increase employment of African-Americans later in the war, but the percentage of such workers is not believed to have risen over 3.2 percent (HOW 1944a:IV:41). Reading between the lines of the official records, it would appear that most of the African-American employees occupied janitorial positions. This assumption was corroborated by Melvin Johnson, who claimed that African-Americans at Holston only performed custodial work (Johnson, interview 1995).

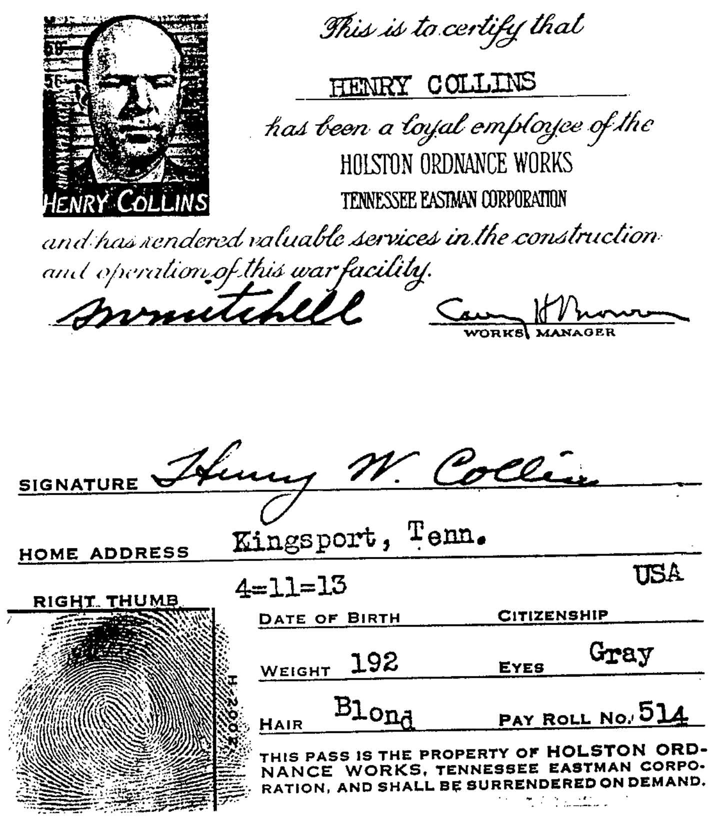
This form of discrimination at Holston was almost surely the result of the Jim Crow laws and attitudes that prevailed in the southern states at that time. Eating and sleeping arrangements were completely segregated by race. The barracks in Area B were divided into facilities for men and women, whites and blacks (HOW 1944d:II:40). There was even a separate recreation room for "colored" dorm residents (HOW 1944d:II:38).

The European-American female employees were much more integral to the operation of Holston. From the start, women held most of the office jobs, but they were soon put on production lines as well (Stauffer, interview 1995). By December 1943, out of a total employment of 5,989, 29 percent (1,710) were women (HOW 1943a:XIII:Exhibit 14). By March of 1944, when there were 2,032 women and 4,798 men, the number of women went up to 30 percent (HOW 1944d:I:16). By August 1944, the female percentage of the work force had declined slightly, and by November it would drop to 28 percent. Ironically, the percentage of women working in the production lines remained about the same during this period and was always higher than the percentage of women working in other areas of the plant. As a rule, women comprised between 32 and 34 percent of the production line work force throughout 1944, in contrast to 22 to 23 percent in other areas of work (HOW 1944b:XII:35, 1944c:VIII:44, 1944c:X:54, 1944d:I:16).

Even though women were well-represented on the production lines, they were not equally distributed. As a rule, they had positions in the Composition B incorporation area rather than in RDX production. The RDX lines were staffed mostly by men throughout the war (Johnson, interview 1995).

Everyday Life at the Plant

By almost all accounts, everyday life at Holston Ordnance Works was relatively harmonious and efficient. Local patriotic fervor remained high throughout the war, and most workers, whether male or female, were glad to have such relatively high-paying jobs. With these jobs, however, came responsibilities above and beyond normal factory work. Security was tight, and all employees were issued picture identification cards which had to be presented upon entering the plant (Figure 42). Even though there was some problem with absenteeism, this was usually because many workers, raised in a rural setting, were not used to the time-clock requirements of factory work. This problem was attacked by staging competitions between different departments for the best attendance record (Figure 43).


HENRY COLLINS

This is to certify that

HENRY COLLINS

has been a loyal employee of the

HOLSTON ORDNANCE WORKS

TENNESSEE EASTMAN CORPORATION

and has rendered valuable services in the construction and operation of this war facility.

WORKS MANAGER

SIGNATURE Henry W. Collins

HOME ADDRESS Kingsport, Tenn.

RIGHT THUMB

DATE OF BIRTH 4-11-13 CITIZENSHIP USA

WEIGHT 192 EYES Gray

HAIR Blond PAY ROLL NO. 514

THIS PASS IS THE PROPERTY OF HOLSTON ORDNANCE WORKS, TENNESSEE EASTMAN CORPORATION, AND SHALL BE SURRENDERED ON DEMAND.

Figure 42. A Holston Identification Card, dated circa 1944 (courtesy of Henry Collins).

Despite the overall harmony of the plant, there was not much in the way of recreation for plant employees. Unlike many munitions factories, Holston did not have a plant newspaper; employees had to make do with the TEC publication, known as the "Tennessee Eastman News" (Herring, interview 1995). The Holston

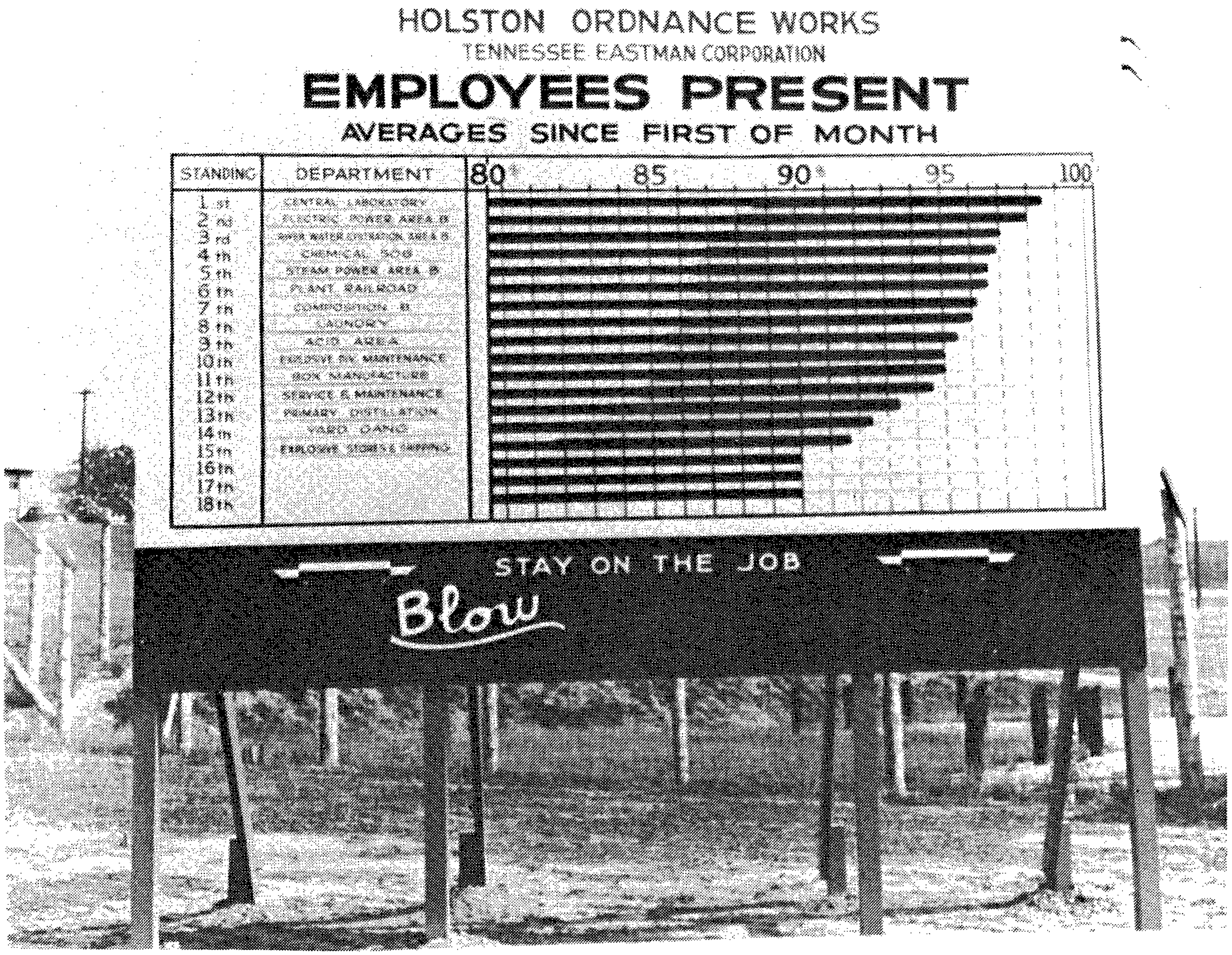


Figure 43. Attendance Ratings Billboard, Holston Ordnance Works (courtesy of Holston AAP Historical Files [on file Thomasson, Building 26]).

Recreation Center was not opened until December of 1943 and was situated in the same pre-war barn that had been used as a cafeteria during plant construction (Figure 44). Open from 9 a.m. to 11 p.m., six days a week, and on Sundays from 3 to 11 p.m., the recreation center featured movies and dancing at regular intervals. On occasion, the center was given over to the plant's African-American employees for dance socials (HOW 1944b:XIII:6).

The overwhelming concern at Holston was clearly not recreation but safety, and every effort was made to ensure the well-being of employees, especially those that worked in the acid areas and on the production lines. Ordnance officials throughout the GOCO system stressed that safety was the primary consideration at all munitions plants, followed closely by quality. Efficiency, or quantity, was only third in priority (Thomson and Mayo 1991:130-131).

To impress upon employees the danger of RDX, all newcomers to the plant were given a practical demonstration of the difference between TNT and RDX. Small amounts of both were detonated on top of steel plates. TNT only dented the plate; RDX punched a hole clean through. This demonstration was followed by a wide array of rules and regulations, particularly stringent for workers on the production lines. Special cotton clothing had to be worn to work and washed at the end of every shift. Workers themselves had to bathe after work, to ensure that no one left the plant contaminated with RDX. In the nitric acid area (503), the fumes were so severe that cotton could not stand up to regular use; employees there had to wear wool (Johnson, interview 1995).

The incorporation areas were of particular concern, for it was here that RDX was in its most dangerous state. The floors of the incorporation buildings were kept wet as a precaution against sparks. The incorporation kettles were powered by steam, piped over from Building 200, for exactly the same reason (Herring, interview 1995; Johnson, interview 1995).

The safety procedures at Holston appear to have been effective. Only three people died during the operation of Holston Ordnance Works, and none as a result of mishap on the production lines. Most accidents were of a minor nature and were always posted as a goad to reduce the level of accidents and injuries (Figure 45). Holston had one of the best accident records of any GOCO facility during World War II, and was infinitely better than the safety record of World War I munitions plants. Overall, it has been estimated that there were more health problems from sore feet than there were from exposure to RDX and TNT (HOW 1944d:II:43).

While safety was stressed at Holston, it would appear that efficiency was not curtailed. On 6 December 1943, Holston employees won their first Army-Navy "E" award, the coveted prize for munitions productivity. Holston Ordnance Works helped turn the tide of World War II and ended up producing some 90 percent of the RDX used by this country in the war. Every former employee interviewed expressed pride in having been a part of that achievement.

Environmental Legacy

While the Holston safety and production record was unsurpassed, its environmental legacy left something to be desired. Even though the Bachmann Method used less nitric acid and was thus less toxic than the Woolwich process, the construction and operation of Holston led to considerable environmental damage, especially to the Holston River. The river was plagued by a number of pollution problems in the 1940s, many of which could be traced to Holston. Perhaps the worst incident was the flushing of Area A prior to construction when the acids left over from World War I munitions plants were washed into the river (Doerr 1945). Pollution was particularly bad in the summer drought of 1944, when the river reached record low levels and was clogged with paper pulp and other solid materials from the Kingsport area (HOW 1944c:VIII:20). All of this was considered secondary to the main goal of winning the war, but the environmental record of Holston, unlike its other legacies, was not unblemished.

Figure 44. Holston Recreation Center in converted barn (courtesy of Holston AAP Photo Set No. 6-B [on file Engineering Vault, Building 26]).

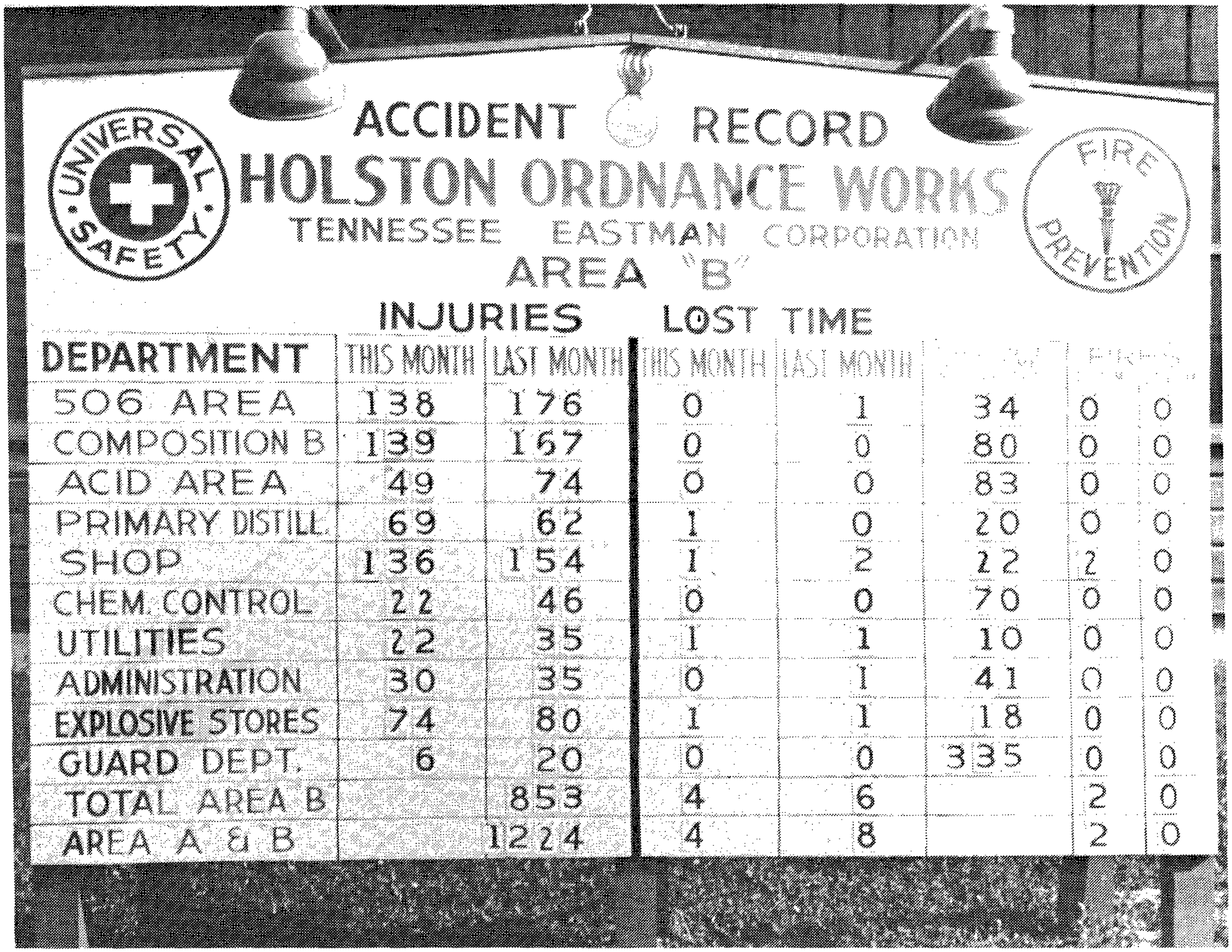


Figure 45. Safety Record Billboard, Holston Ordnance Works (courtesy of Holston AAP Historical Files [on file Thomasson, Building 26]).

TOWARD THE END OF THE WAR

By V-E Day (Victory in Europe), Holston Ordnance Works was considered the largest explosives plant in the world. Ironically, V-E Day, 8 May 1945, was also the second anniversary of RDX production at the plant (HOW 1945a:II:10). At that time, Holston was in full production, with no end in sight. The war in the Pacific appeared far from over, and RDX was still in high demand.

By the end of July, government officials knew that the atom bomb was near completion and would almost surely end the war against Japan. For this reason, Holston received a War Department directive on 21 July 1945, stating that the plant production quota was no longer to be exceeded. In order to comply, line 9 was shut down on 24 July (HOW 1945d:VIII:1).

On 6 August 1945, an atomic bomb was dropped on the city of Hiroshima; three days later, a second bomb was dropped on Nagasaki. Within a week, Japan indicated its desire to surrender, which was made formal by the signing of documents on the Battleship Missouri on 2 September. During this period, Holston Ordnance Works went into rapid eclipse as production lines were shut down and employees laid off.

In July, Holston still had a work force of some 5,040 people (HOW 1945d:VII:29). On 6 August, Holston received a directive that production was to be limited to one line; all others were to go on stand-by. Before the end of the month, all production ceased except on line 4. Employees were laid off as fast as their terminations could be processed—more than 3,000 were let go in August alone. Some employees, however, were transferred to Tennessee Eastman (HOW 1945d:IX:3-4).

At the beginning of September, when the Composition B Department was disbanded, there were only some 1,700 employees left at the plant (HOW 1945d:IX:12, 17). The numbers continued to decline through September and October. On 6 October, Carey Brown, the Holston works manager, left for other employment (HOW 1945c:I:5), following the trail of many others during that same period. When the government announced the end of the Holston contract on 18 November 1945, there were only 122 people remaining on the payroll (HOW 1945c:I:7). At this point, most de-activation and final inventory work had been completed, and Holston was turned over to the Ordnance Department for further stand-by operations (HOW 1945c:I:1). By the end of the year, the stand-by workforce at Holston had stabilized to around 300 employees (HOW 1945c:II:2).

POST-WAR YEARS

Holston Ordnance Works remained on stand-by from the end of 1945 to early 1949 (Farthing and McLain 1952; Kane 1995:58). In 1946, the facility was used to store 18,500,000 pounds of Composition B, shipped from Bluebonnet Ordnance Plant in McGregor, Texas (HOW 1946:1-4). Plans were also made to dispose of some portions of Area B, especially in the area of the Rotherwood House, which was divested by the government during this period.

As the Cold War began to take shape in the late 1940s, there was once again a demand for RDX and other related high-explosives. Holston was reinstated in April of 1949, when the facility began small-scale production under the auspices of a new Eastman subsidiary, the Holston Defense Corporation (MacDonald and Mack 1984:45; Rotary Club 1951:309; Siegel et al. 1982:11).

The following year, just as the Korean War began, Holston was in the news as the focus of a spy trial. On 15 June 1950, Alfred Dean Slack was arrested by the Federal Bureau of Investigation (FBI) in Syracuse, New York, for having passed RDX secrets to a Soviet agent during World War II. Slack, an Eastman Kodak employee who had worked at Holston in 1943 and 1944, was convicted of espionage and sentenced to prison (Rotary Club 1951:311; Wolfe 1987:163).

By the time Slack came to trial, the United States was embroiled in the Korean War, which led to a dramatic increase in the demand for RDX. The John J. Harte Company of Atlanta was awarded a contract in January 1951 to refurbish parts of Holston for a large-scale resumption of RDX and Composition B production (Rotary Club 1951:309). It was about this time, in 1951, that the TEC changed its name to the Tennessee Eastman Company (Holston Defense Corporation 1992).

The 1950s and 1960s saw a great number of changes in Holston production techniques. Most of these changes began with the Korean War and continued in the years that followed. During that conflict, Holston had eight production lines in full operation. HMX, or homocyclonite, was developed as an eventual successor to RDX, and this development continued after the Korean armistice when Holston production was cut back to one line (MacDonald and Mack 1984:45-46).

HMX is closely related to RDX, differing only slightly in molecular structure (Fletcher, personal communication 1995; Holston Army Ammunition Plant c. 1968). First isolated and identified as a result of the Bachmann process, HMX had been studied since the early days of World War II, but even though it was more powerful than RDX, it was considered too expensive to manufacture in the 1940s (Holston Defense Corporation 1992:1.8).

By the late 1950s, enough data on HMX had been collected to begin limited production at Holston. Line 6 and others were modified in 1957-1959, with HMX production beginning around 1961. This initiated an era when modifications to many of the Holston production lines were introduced. Some lines were re-tooled for HMX; others concentrated on mixtures such as Composition A-3—a combination of RDX and wax (Miller, personal communications 1995). Changes were also made to the incorporation buildings so that Buildings I, J, L, and M were no longer identical in function.

Other changes were made in the systems that supported the production lines. Pipelines were laid between Areas A and B so that acetic acid and acetic anhydride could be pumped back and forth without the need for railroad cars. An even greater technological change occurred in the nitric acid area (503), where ammonium nitrate was made through a continuous process with a magnesium catalyst (Joe Davy, personal communication 1995). Known as "maggies," or "maggie units," these processors brought the nitric acid facilities of the 503 Area to the full continuous feed potential that had long been attained in Area A with acetic acid and acetic anhydride.

The worst disaster known to have occurred at Holston took place on 28 May 1957, when a fire and explosion rocked Building D-4 during a trial run of HMX production. No one was killed, but Raleigh Dingus, one of the interviewees, remembered the explosion well, since he worked for the Holston fire station at the time (Dingus, interview 1995; Holston Defense Corporation 1963).

In 1963, in the wake of Secretary of Defense Robert McNamara's overhaul of the military organization, Holston Ordnance Works was redesignated Holston Army Ammunition Plant (Holston Defense Corporation c. 1990:4; MacDonald and Mack 1984:21). Within a few years, the renamed facility began to gear up for the Vietnam conflict, which kept the plant running well into the 1970s.

By the 1980s, Holston had assumed the layout and functions characteristic of the 1990s. In addition to the new pipelines and maggie units, a number of other buildings have been erected since World War II. Among these were Building 151 (Central Hexamine) and Building 149 (Lacquer Mixing and Central Solvent) (Holston Defense Corporation c. 1990:20). In the late 1980s, Holston was the only facility in the United States still manufacturing RDX and HMX-based explosives (Kane 1995:58). The majority of the 77 GOCO industrial facilities constructed for World War II were eliminated by the 1990s. Only 27 survived as Army ammunition plants (Kane 1995:1). Holston was one of the survivors, even though its present production capacity is essentially limited to the equivalent of one line (Fletcher, personal communication 1995).

This was the status of Holston when the first cultural resource management (CRM) study was conducted at the facility. CRM work appears to have begun in April 1983, with a historic properties survey that was published in 1984 (MacDonald and Mack 1984:3). By that time, the TEC pilot plants at Wexler Bend and Horse Creek were gone, and only production lines 2 and 9 resembled their World War II design (Miller, personal communication 1995). The main contractor for the CRM study was Building Technology, Inc., which operated through two major subcontractors—Jeffrey Hess and the MacDonald and Mack Partnership. Hess appears to have done most of the historical research (Hess 1984), which was then incorporated into the MacDonald and Mack report (1984).

As a result of the 1984 CRM research, the World War II buildings of the 10 production lines in Area B were designated Category I properties, or historic properties of the highest significance. Also designated Category I was the Producer Gas Plant (Building 10) in Area A. The Old Administration Building (Building 1) in Area B was listed as Category III, which signifies minor importance. No structures received the designation of Category II (MacDonald and Mack 1984:i).

Two years later, the Category I designation for the manufacturing area in Area B led to Historic American Engineering Record (HAER) documentation of a typical World War II production line. Line 9 was selected for study, since it was one of the least altered of the 10 production lines. This work resulted in a full HAER report on the World War II facility, complete with axonometric drawings and historical text (Historic American Engineering Record TN-10, 1986).

SUMMARY AND CONCLUSIONS

Holston Ordnance Works was one of the most significant of the many GOCO facilities constructed during World War II. It produced the majority of the RDX and Composition B made in the United States, and had a decided impact on the war effort when the plant went into production in early May of 1943. Within just a few months after Holston went into production, the power struggle within the Atlantic shifted in favor of the Allies, due in part, to the increased supply of RDX and Composition B. The production capacity at Holston also paved the way for the massive materiel build up in Britain that made Operation Overlord, the invasion of Normandy, possible in June of 1944.

Although the achievements of Holston are noteworthy, they would not have transpired without the contributions of Tennessee Eastman and the TEC pilot plants. The Holston success was predicated on the prior achievements of the Wexler Bend and Horse Creek pilot plants, both of which operated as models for the Holston Ordnance Works. The story of Holston is inextricably intertwined with those of the pilot plants and the company that ran them, the TEC.

For all of the administrative problems engendered by the dual nature of the GOCO facilities, it was a system that worked well, relying on private initiative and government overview, a sensible blend of competition and cooperation. GOCO facilities were essential to winning the war, not only for American forces, but for all the war-time recipients of Lend-Lease aid.

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